Draft Standard Operating Procedures for Analysis of Gaseous and Fine Particulate-Bound Mercury

Version 2.0

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Asterisks located in this SOP denote that additional information is available in the Technical Support Commentary document.

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PREFACE

Standard Operating Procedures for Analysis of Gaseous and Particulate Mercury describes how to properly operate and maintain an automated speciated ambient mercury monitoring unit. This document ensures the systematic planning in the collection of ambient mercury data. The systematic planning behind this standard operating procedure has been developed from a best practices questionnaire distributed by the National Atmospheric Deposition Program (NADP) to detail the operation of an automated speciated ambient mercury monitoring unit. Atmospheric mercury scientists throughout North America convened to discuss the best practices for monitoring for ambient mercury. These discussions were held at the NADP Atmospheric Mercury Scientists Workshop held in Chicago, IL on October 3-4, 2007.

This SOP continues with efforts started at special meeting at the NADP Spring Conference in Riverside, CA on May 1, 2006; an Atmospheric Mercury Scientists Workshop in Chicago, IL on June 27, 2006; the NADP Fall Conference in Norfolk, VA on October 24-26, 2006; the NADP Spring Conference in Underhill, VT on April 9-10, 2007; and the Atmospheric Mercury Best Practices and SOP Workshop October 3-4, 2007.

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Standard Operating Procedures for Analysis of Gaseous and Particulate Mercury

1.0 Scope and Application

This Standard Operating Procedure is applicable to the collection of ambient mercury concentrations using an automatic speciated ambient mercury monitoring unit (Figure 1). This method is for determination of mercury (Hg) in the range of 0.001 to 50 nanograms/cubic meter (ηg/m^3 as Hg).

2.0 Summary of Method

The term Reactive Gaseous Mercury has become accepted through usage. However, the term "reactive" is at best misleading and very imprecise. We propose that this SOP could serve to correct this problem and set proper definitions for the long-term. Eric Prestbo, Tekran, Inc. (Toronto, ON) suggested that consistency and correctness would be better served if we used GEM, GOM, and PBM2.5. Gaseous Oxidized Mercury (GOM) is more descriptive and accurate than is reactive gaseous mercury (RGM). Gaseous elemental mercury (GEM) is commonly used. Particulate-Bound Mercury ($PBM_{2.5}$) is better than particulate mercury, because the latter implies there are particles of mercury rather than mercury on/in particles. These new terms, GOM and $PBM_{2.5}$, are used throughout this SOP.

The method was developed and performance tested under the direction of the USEPA Office of Research and Development and Florida State Department of Environmental Protection (Landis et al., 2002). The method is a real-time selective separation of gaseous oxidized mercury (GOM), fine fraction particulate-bound mercury ($PBM_{2.5}$) and gaseous elemental mercury (GEM) with subsequent detection by automated pure gold cartridge pre-concentration and cold vapor atomic fluorescence spectroscopy (CVAFS).

Ambient air is pulled under vacuum through an impactor inlet to remove particulate matter greater than 2.5 µm and then through a potassium chloride (KCl) coated quartz annular denuder to selectively adsorb GOM, with GEM and $PBM_{2.5}$ passing through the denuder. The air stream then passes through a regenerable particulate filter (RPF) assembly to selectively capture $PBM_{2.5}$ while the remaining mercury fraction, GEM, quantitatively passes through and is captured on pure

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gold cartridges to complete the quantitative separation and collection of the mercury fractions.

The mercury fractions must be in the GEM form for quantitative transfer and pre-concentration on gold cartridges and subsequent detection by the automated CVAFS. Mercury is thermally desorbed from the gold cartridge in an ultra high purity argon stream that carries the released Hg^0 into the cell of a cold-vapor atomic fluorescence spectrometer (CVAFS) for detection.

During GOM and $PBM_{2.5}$ sample collection, GEM in air is continuously being collected on alternative A and B gold cartridges and analyzed by the automated CVAFS detector at 5-minute intervals. After a predefined time (e.g. 2 hours) the automated system switches to $PBM_{2.5}$ and GOM analysis. During this period, the system thermally converts and desorbs in succession the $PBM_{2.5}$ and GOM at high temperature to the GEM form in a stream of mercury-free (zero) air for pre-concentration on gold cartridges and subsequent CVAFS detection.

Quality of the Tekran 2537 is assured through calibration on a set interval by an automated internal, temperature controlled mercury permeation source within the detector (Poissant, 2008). Other quality assurance steps include external intrinsically NIST traceable mercury permeation source verification, various performance tests, leak checks, routine maintenance and high frequency data quality criteria review by an automatic computer program.
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Table 2.1 Schedule: On-Site Equipment Maintenance and QA Checks
Bi-weekly
Install new blanked GOM denuder
Install trace-clean GL14-GL18 union (Luke, 2008)
Install trace-clean inlet glassware including new frit
Install new pre-purged soda lime trap
Install trace-clean zero air filter housing and new filter media in 1130
Install trace-clean sample line filter housing and new filter media in 1130
Check lamp voltage – adjust and recalibrate as needed
Check dri-rite (or similar) on outlet of air dryer and replace as necessary (Miller, 2008a)
Leak check the entire system by zero-air vacuum method
Monthly
Install trace-clean 2537 sample filter housing and new filter media in 2537 (Holsen & Choi, 2008)
Install trace-clean 2537 zero air filter housing and new filter media in 2537 (Holsen & Choi, 2008)
Confirm inlet volumetric flow rate is between 8.0 to 11.0 L/min (Miller, 2008b)
4-6 Weeks
Install new blanked regenerable particulate filter assembly
Install trace-clean RPF 3/8" to ¼" Teflon elbow fitting and Teflon tubing (Luke, 2008)
Rinse Teflon tubing extending from soda-lime trap to 2537 sample filter with DIW and methanol
Quarterly
Audit the mass flow controller in the 2537
Audit the mass flow meter in the 1130 pump module
Verify the 2537 internal mercury permeation tube emission rate by syringe injection
Check the nichrome gold cartridge heating coils, reseat and tighten electrical connection and confirm operation by "red" color at peak of heating cycle
Check and synchronize Tekran clock to NIST time source (Miller, 2008a)
6 Months
Rinse or install new, trace-clean Teflon tubing at key locations in the 1130 pump module and/or prior to the heated line (Miller, 2008a)
Change both of the 1130 pump unit zero air carbon canisters and DFU filters
Monitor the instrument shelter air – check for possible indoor Hg sources (Miller, 2008a; Steffen, 2008) – see Section 4.2.5.1
Annually
Replace the nichrome gold cartridge heating coils
Install new 2537A zero air canister and DFU filter if needed
Rinse or install new Teflon tubing at key locations between the 2537 and 1130 including the heated sample line
Replace GL14-GL18 union fitting between denuder and RPF
Verify the 2537 internal mercury permeation tube emission rate by independent QA audit technician
Maintenance on 1102 or other zero air system (Felton, 2008)
Replace the 1130 pump diaphragm and brushes (Olson, 2008)
As needed
Maintain the 2537 pump with needed new parts dependent on model type (KNF UN89 or KNF N79
Install new match-pair pure gold cartridges within the 2537
Clean or install new 2537 Teflon valves
Replace/clean quartz fluorescence cell
Replace the 2537 lamp due to age and poor performance

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Table 2.2 Consensus NADP-AMI Tekran Model 1130/1135 Controller Program Worksheet

DRAFT NADP-AMI TEKRAN MODEL 1130/1135 CONTROLLER PROGRAM WORKSHEET

Controller S/W revision:

Description of this Method:

Notes: 1) Flow rate set for near sea-level sites. Sites at higher elevation may adjust to keep volumetric flow at 10 lpm. 2) A 1-hour adsorb time - 1 hour desorb cycle is an acceptable alternative for special source-receptor study sites. The sample durati

Model 2537 Settings

Cycle Time: (sec)	300
Flow Rate: (L/m)	1.00

Pump Module Settings

Sample Flow: (L/m):	9.00
Desorb Flow: (L/m)	6.00

Model 1130 Denuder Module Temperature Settings (deg C)

SP1	Case Heater:	38
SP2	Case Fan:	40
SP1	Heated Line:	50
SP1	Denuder Keep Warm:	50
SP2	Denuder Heat:	500
SP1	Ext. Heat:	75
SP2	Ext Keep Warm:	50

Model 1135 Particulate Module Temperature Settings (deg C)

SP1	Pyrolyzer Keep Warm:	50
SP2	Pyrolyzer Heat:	800
SP1	Part-Trap Keep Warm:	50
SP2	Part-Trap Heat:	800
SP1	Case Heater:	38
SP2	Case Fan:	40

Calculated Values

5.00	Model 2537 Sample Volume (L)
10.00	Denuder Flow Rate (L/m)
1,200	Denuder Total Volume (L)
0.00417	Model 2537 Factor (for ng/m3)
4.167	Model 2537 Factor (for pg/m3)
120	Denuder Sample Time (min)
60	Desorb Analysis Time (min)
180	Total Cycle time (min)
72.0	Auto-Recal interval (hours)

Note: Denuder figures above also apply to the particulate trap.

Au Cartridge Status (GOM & PBM2.5 1st Heat)

Step	Cartridge	Cartridge	Cartridge
1	A	B	A
2	B	-	-
3	**A**	B	A
4	**B**	A	
5	B		
6	A	B	-

Controller Settings

Step No.	Step Label	Step Duration	Duration Units	Event Flags 0 - 7	Sync N=0, Y=1	1130 H/C Mask	1135 L/C Mask	Cumulative Time (sec)	Notes	Time (hrs)
	Auto-Cal	24	GOM-Cycles	n/a	n/a	n/a	n/a			
0	Sample Duration	24	2537 Cycles	0	0	0	0	7200	GOM and PBM2.5 Adsorb tim	2.00
1	Flush	890	sec	1	1	9	0	8100	Three cycle initial flush	2.25
2	Pyro-Ht	290	sec	2	1	9	4	8400	Pyrolyzer preheat	2.33
3	Part-Ht	890	sec	2	1	9	12	9300	Particulate trap heat	2.58
4	GOM-Ht	600	sec	3	0	13	12	9900	Start GOM Heat	2.75
5	GOM-Ht2	290	sec	3	1	13	0	10200	GOM Ht - Stop Py/Pt Ht	2.83
6	Cool	590	sec	1	0	3	2	10790	Two cycle cool	3.00
7	Wait	1	sec	1	1	1	0	10800	Zero air during Sync Period	3.00

Notes:

1) If the Model 2537 is not in **RUN** mode, or if it stops drawing air through its **Sample** inlet (eg: it stops or the **Zero** solenoid is activated, the controller will immediately jump to the **WAIT** (7) state and wait there until the Model 2537 reenters normal **RUN** mode.
2) A step duration of **0** will cause the step to be skipped entirely.

Event Flags:

1) If the controller changes state midway through a 2537 sample cycle, the resultant event flag will be the logical OR of the flag settings for the individual steps.
2) Event flag status is not sampled for the initial few seconds of each 2537 cycle. If step changes are to occur asynchronously with respect to the sample cycle, the change should occur 1 second ***after*** a cycle change to prevent spurious flag values from being registered. If **Sync=1**, the transition will always occur at the correct time.

Sync:

If Sync is set to Yes (1), the controller will pause at the current step until a Model 2537 cycle transition is detected, even after the duration time expires. The duration should expire at least a few seconds before the expected cartridge switchover.

Model 1130: H/C Mask Functions: Add numeric values to determine total functions activated during the step

1 Zero Air ON, Desorb Flow RateSelected
2 Denuder Cooling
4 Denuder Heat
8 External Heat

Model 1135: L/C Mask Functions: Add numeric values to determine total functions activated during the step

1 Aux-1
2 Particulate Cooling
4 Pyrolyzer Heat
8 Particulate Heat

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There have been a number of comments posted to the previous version of this SOP indicating that atmospheric mercury experts use a number of different techniques to reduce their data – and most feedback on the subject indicated that the previously proposed data reduction scheme is not ideal. Listed below are data and comments to the previously proposed data reduction routine which include suggestions from a number of atmospheric Hg experts. A newly proposed data reduction routine is presented here and discussion on this topic is highly encouraged. Additionally, a Data Reduction Survey was distributed and the results from this survey are also included.

Proper use of Tekran equipment in a methodical, skilled manner will preempt operational problems and will lead to high quality data. Users' unique data reduction routines appear to be most divergent among poor quality data. Therefore, with skilled operation, the use of unique data reduction routines and other data screening techniques should become a moot point in terms of providing consistent, high quality data.

Table 2.3 – Tekran GOM and PBM2.5 Data Reduction Routines

Tekran Desorb Program				**Tekran GOM and PBM2.5 Data Reduction Routines**		
Cycle ID	**Description**	**Flag**		**USER-ID**	**PBM2.5 Calculation**	**GOM Calculation**
A	**Flush**	**1**				
B	**Flush**	**1**			**(E+F+G)-3*C**	**(H+I+J)-3*C**
C	**Flush**	**1**				
D	**Pyro-Ht**	**2**				
E	**Part-Ht**	**2**				
F	**Part-Ht**	**2**				
G	**Part-Ht**	**2**				
H	**RGM-Ht**	**3**				
I	**RGM-Ht**	**3**				
J	**RGM-Ht2**	**3**				
K	**Cool**	**1**				
L	**Cool**	**1**				

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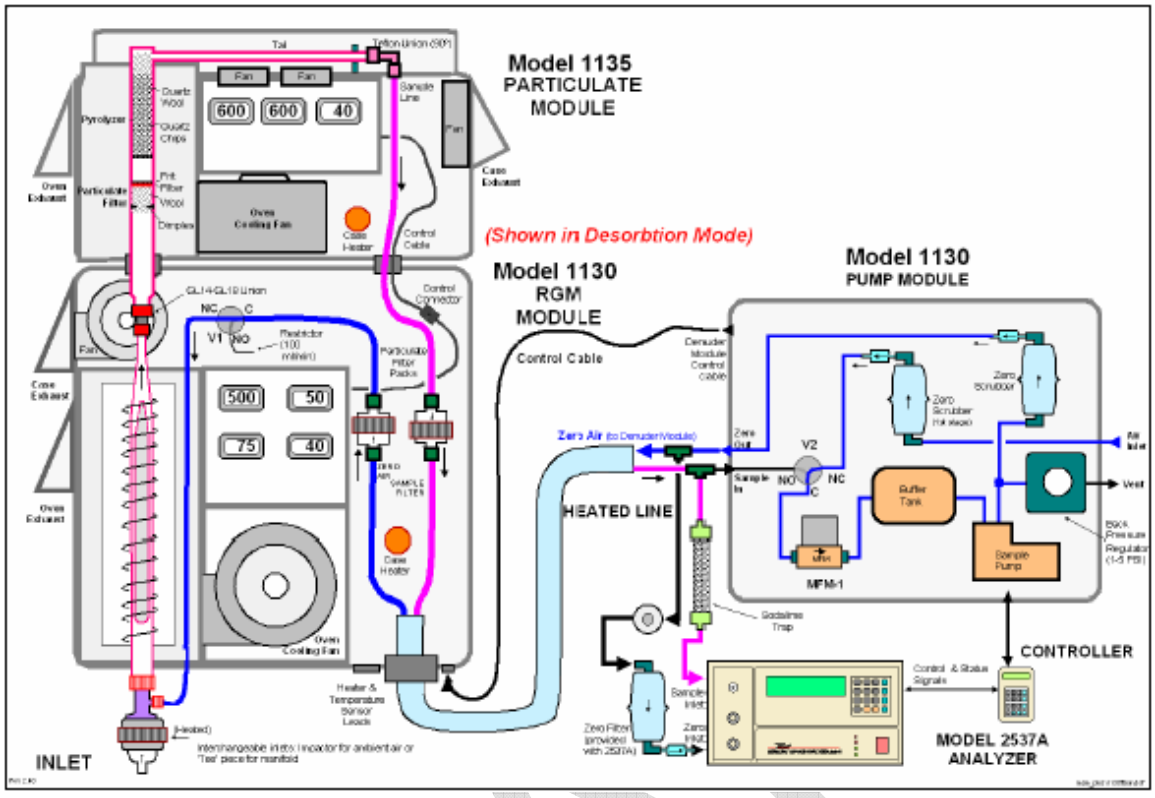

Figure 1 - Tekran Speciated Mercury Vapor Analyzer (Tekran, 2006b)
note: Display numbers should be 800/800/38 and 500/50/75/38 (Olson, 2008)

3.0 Definitions

3.1 Methods

(Additional expert mercury monitoring feedback in this issue is recommended.)

4.0 Contamination and Interferences

Adapted from (US-EPA, 2002)

4.1 Preventing contamination

Preventing samples from becoming contaminated during the sampling and analysis process constitutes one of the greatest difficulties encountered in trace metals determinations. Therefore, it is imperative that extreme care be taken to avoid contamination when collecting and analyzing samples for trace metals. For the automated ambient air mercury speciation system, this translates into using the trace metal clean concepts described in EPA Method 1669, when preparing, storing and installing any parts in the air-contact flow stream. The combination of continuous flow and cyclical heating of the automated ambient air mercury speciation system means that over time it can be

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self-cleaning if contamination occurs. Thus, if there is low-level contamination, patience may be the best course of action. However this self-cleaning mechanism is not a replacement for careful lab and field work to avoid contamination.

The air-flow sample stream may become contaminated by numerous routes. Potential sources of trace metals contamination during preparation, storage or installation of parts in the air-contact flow stream include: metallic or metal-containing labware (e.g., talc gloves that contain high levels of zinc), containers, sampling equipment, reagents, and reagent water; improperly cleaned or stored equipment, labware, and reagents; and atmospheric inputs such as dirt and dust. Even human contact can be a source of trace metals contamination. For example, it has been demonstrated that dental work (e.g., mercury amalgam fillings) in the mouths of laboratory personnel can contaminate air-flow sample streams directly exposed to exhalation or saliva. Cleaning, preparation and storage of replacement parts in the laboratory should be done in a low-mercury (<30 ng/m^3), low-particulate environment.

4.2 Contamination Control

4.2.1 Philosophy – The philosophy behind contamination control is to ensure that any object or substance that contacts any part in the air-flow sample stream (e.g. fittings, tubing, and denuder) is metal free and free from any material that may contain mercury, including but not limited to, human hair, dust, fibers, aerosol matter and very high mercury air present in the working environment.

4.2.2 The integrity of the results produced cannot be compromised by contamination of the air-flow sample path. This Method and the Sampling Method give requirements and suggestions for control of the air-flow sample stream contamination.

4.2.3 The use of mercury calibration standards, pressure measurement devices such as barometers, broken fluorescent lights containing mercury and other such items cannot be allowed to contaminate the field site work area or instrumentation used for trace metals measurements. This method gives requirements and suggestions for protecting the field site work area and surrounding environment.

4.2.4 Although contamination control is essential, personnel health and safety remain the highest priority. The Sampling Method

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and Section 5 of this Method give suggestions and requirements for personnel safety.

4.2.5 Avoiding contamination—The best way to control contamination is to completely avoid exposure of the air-flow sample stream to contamination in the first place. Avoiding exposure means performing operations in an area and with materials known to be free from contamination. Two of the most important factors in avoiding/reducing sample contamination are (1) an awareness of potential sources of contamination and (2) strict attention to work being done. Therefore, it is imperative that the procedures described in this Method be carried out by well-trained, experienced personnel.

4.2.5.1 Section must be added here to describe the need to assess the level of location contamination or possible bias by activities or materials brought within close distance of the field site. For example mercury thermometers, building materials, paint and so forth.

Lessons Learned:
"What we have done in the past is to use the 2537 to test the indoor air [before] we decide to move to a site. We run it for a while at different spots inside and out. Testing the air coming around doors and windows from the outside in order to not have the indoor air contaminate the outdoor air. For RGM/PHg contamination …you'd have to run it the same way I'd imagine." (Steffen, 2008)

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4.2.6 Minimize exposure—The air-flow sample stream parts that will contact sample air, zero air or mercury standard air should be exposed only in a clean room, clean bench, or glove box so that exposure to an uncontrolled atmosphere is minimized. When not being used, the Apparatus should be covered with clean plastic wrap, stored in the clean bench or in a plastic box or glove box, or bagged in clean ziploc-type bags. Minimizing the time between cleaning and use will also minimize contamination. In the field, when installing parts into the instrument, the conditions and exposure time should be optimized to avoid sources of contamination. For example, use clean gloves, change gloves as needed, keep parts in clean storage bags when installing where practical and consider yourself as a point of contamination. Also, it may be wise to turn off sources of high air flow in the shelter such as the heater, air conditioner or fans.

4.2.7 Clean work surfaces—Before air flow sample stream parts (e.g. impactor inlets) are being prepared for use, all work surfaces in

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the hood, clean bench, or glove box in which the samples will be processed should be cleaned by wiping with a lint-free cloth or wipe soaked with reagent-grade water or methanol.

4.2.8 Wear gloves—personnel servicing the instrumentation related to installation or changing air-flow sample stream parts must wear clean, non-talc, nitrile or PVC gloves during all operations involving handling. Only clean gloves may touch the critical parts. If another object or substance is touched, the glove(s) must be changed before again handling the air-flow parts. If it is even suspected that gloves have become contaminated, work must be halted, the contaminated gloves removed, and a new pair of clean gloves put on. Wearing multiple layers of clean gloves will allow the old pair to be quickly stripped with minimal disruption to the work activity.

4.2.9 The laboratory or cleaning facility is responsible for cleaning the air-flow sample stream parts used by the field maintenance team. If there are any indications that the air-flow sample stream parts are not clean or functional when received by the field maintenance team (e.g., noticeable particulate, ripped sample bags, etc), an assessment of the likelihood of contamination must be made. Installation must not proceed if it is possible that the instrument sample flow stream could become contaminated. If the newly installed air-flow sample stream parts are found to be contaminated, they must be returned to the laboratory or cleaning facility for proper cleaning before they can be reinstalled.

4.2.10 Service the 1130 pump unit off site or with great care. A significant contamination risk is the carbon dust generated by the pump motor brushes in the 1130 (and 2537A). Great care should be taken that this carbon dust (or similar generated by other instruments) is not released into the instrument shelter environment or be allowed to contaminate the sample stream. The carbon dust may easily find its way into the instrument flow path and may scavenge Hg. This dust should be removed from the 1130 housing every 6 months during carbon cartridge changes by wiping with damp kimwipe. **Do not blow out with compressed air** as the carbon dust will go everywhere. If you are servicing elements of the sample air stream at the same time, do that first and take great care not to contaminate your shelter or work area. (Miller, 2008a)

"It should be recommended that each site maintain a clean, back-up set of filters and glassware on-site in the event that the primary set to be changed in is found to be contaminated." (Miller, 2008a)

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4.3 Interferences

This section is critical and has yet to be fully flushed out. Please contribute to this section or offer topics not covered by the following list.

4.3.1 High purity argon

The use of high purity argon is very critical to keep the instrument operating properly and reduce the potential for interferences. "An in-line gold trap (Tekran 3025200-00 Gold gas scrubber) is important to ensure no Hg is in the argon supply." (Holsen & Choi, 2008)

4.3.2 Co-collected compounds that are released from the KCl-denuder or RPF

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4.3.3 Use of soda-lime to minimize interferences

Update from Tekran:
"Tekran is about to launch a low-cost, factory and field tested batches of soda-lime traps with date stamp. We will continue to actively track soda-lime experience and support proper use of soda lime" (Prestbo, 2008)

Lessons learned:
"To me this is a big issue. We need to figure out what type of soda lime and how to effectively prepare it. I once baked it on Matt Landis's recommendation and it crapped everything up. Plus we have to stress the indicating vs. non indicating. Some consensus on the brand and mesh size would be needed…" (Steffen, 2008)
"Soda-lime traps placed both before the 2537A inlet and on the 1130 zero-air outlet have been demonstrated to reduce the activity of unspecified interfering elements or compounds that appear to alter the surface of the analytical gold traps causing "passivation" of the surface. Passivation is evident when the GEM readings post desorption of the denuder are significantly lower than the GEM readings immediately prior to desorption. The GEM readings then subsequently recover to the prior values over the course of the 1 to 2 hour denuder/RPF accumulation interval. However, not all suppliers or batches of soda lime from a given supplier and satisfactorily free of mercury for use. Most soda lime requires some period of purging with

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mercury-free air to remove weakly surface bound mercury. Soda lime batches must be tested to determine if the standard purge treatment provides satisfactorily clean soda lime." (Miller, 2008b)

4.3.4 Suspected iodine compound Au cartridge passivation effects that can occur if zero air canisters become wet.

Update from Tekran:
"Tekran is about to launch a model 1102 zero air dryer modification kit to absolutely remove this potential interferant. It will include capping the V1 valve in the 1130 denuder module. In addition, some users have found that regular activated carbon canisters are providing good zeros and may be a solution as well. This interferant is avoidable and the SOP can reflect this…." (Prestbo, 2008)

4.3.5 Selectivity and avoidance of interferences due to the real-time separation during sampling (e.g. 2.5 µm cut size), selectivity of the method by gold-cartridge pre-concentration and atomic fluorescence.

4.3.6 No interferences for ambient air levels of SO2, O3, and other air pollutants have been observed when challenged by careful experiments.

Lessons learned:
"We should make a note to be careful about other instruments collecting ancillary data …they calibrate and produce O3 …something to be aware of when discussing interferences" (Steffen, 2008)

5.0 Health and Safety

Adapted from (US-EPA, 2002)

5.1 Toxicity

The toxicity or carcinogenicity of each chemical used in this Method has not been precisely determined; however, each compound should be treated as a potential health hazard. Exposure to these compounds should be reduced to the lowest possible level.

5.1.1 Chronic exposure

Chronic mercury exposure may cause kidney damage, muscle tremors, spasms, personality changes, depression, irritability and nervousness. Organo-mercurials may cause permanent brain damage. Because of

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the toxicological and physical properties of Hg, pure standards should be handled only by highly trained personnel thoroughly familiar with handling and cautionary procedures and the associated risks.

5.1.2 Safety and use

This Method does not address all safety issues associated with its use. The laboratory and field site is responsible for maintaining a current file of OSHA regulations for safe handling of the chemicals specified in this Method. OSHA rules require that a reference file of material safety data sheets (MSDSs) must be made available to all personnel involved in these analyses.

5.1.3 Laboratory and Field-Site safety

Standard concentrations of Hg at elevated levels are handled using essentially the same techniques employed in handling radioactive or infectious materials. Well ventilated, controlled access laboratories are required. Assistance in evaluating the health hazards of particular laboratory conditions may be obtained from certain consulting laboratories and from State Departments of Health or Labor, many of which have an industrial health service. Each laboratory and field site must develop a safety program for handling Hg.

5.1.3.1 Protective equipment

Use of protective equipment such as gloves is normally used to keep mercury contamination from the sampling system. However, certain tasks may require handling of mercury standards or solutions where disposable plastic gloves, apron lab coat, safety glasses or mask, and a glove box or fume hood adequate for radioactive work should be used. During analytical operations that may give rise to high levels of gaseous mercury or aerosols (e.g. transferring liquid mercury for a calibration system), personnel should wear respirators equipped with activated carbon filters as needed.

5.1.3.2 Training

Both lab and field site technicians must be trained in the proper method of removing contaminated gloves and clothing without contacting the exterior surfaces.

5.1.3.3 Effluent vapors

The amount of mercury in the sample and standards is exceedingly small and does not pose a risk in the majority of cases. However, one must consider whether the effluent from the CVAFS should pass through either a column of activated charcoal or a trap containing gold or trap any mercury vapors.

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5.1.3.4 Waste handling

Good technique includes minimizing contaminated waste.

Lessons learned:
"Never discard old Hg lamp in normal garbage. Special regulation about hazardous materials." (Poissant, 2008)

5.2 Compressed gas cylinder safety (NOAA, 2006)

Compressed gas cylinders require basic attention to safety to prevent injury to the operator or equipment.

During operation or storage, always secure gas cylinders upright to a permanent object by straps or chains to prevent them from falling. Dropping a gas cylinder could break off or damage the valve, which would create an extremely dangerous situation.

When moving gas cylinders, always ensure that the valve protection caps are on, that the cylinder is secured in an upright position, and only vehicles or hand trucks designed for transporting gas cylinders are used. Gas cylinders may be rolled on their bottom edge for short distances only.

When a gas cylinder is empty, close the main cylinder valve before removing the regulator, fit protection caps over the valve and mark the cylinders as empty.

Ensure that all argon cylinders are labeled Ultra-High-Purity (or UHP, 99.999%) argon. Also ensure that no helium has been used in this cylinder before, as helium will shorten the lifetime of the Tekran 2537 unit lamp (Felton, 2008).

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6.0 Maintenance, Equipment and Supplies

6.1 Schedule: Equipment maintenance and QA checks

Equipment maintenance details were separated into on-site and in-lab procedures to ensure that components are prepared using similar techniques under similar conditions. This information should also help minimize weather and/or contamination issues.

6.2 Site-visit/remote access on-site equipment maintenance and QA checks

Table 6.2 Site-visit/remote access on-site equipment maintenance and QA checks

Site-visit/remote access on-site equipment maintenance and QA checks	
Action required:	Work through operator site-visit/remote access data checklist
Maintenance required:	None
Consumables required:	None
Tools required:	None

During each site visit or through remote access, the operator should complete an operator site-visit/remote access data checklist. This checklist provides a surficial examination of the ambient mercury monitoring system to ensure that there aren't any obvious mechanical faults.

The operator site-visit/remote access data checklist is found in the appendix.

Lessons Learned:
"Daily on-site checks can be replaced with automated or remote daily checks via data logger and appropriate software. In our system the data logger checks each of these daily parameters and more and sends a text message to PI and site operator cell phones if anything is out of spec. If operator makes any adjustments to the system they get

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logged in an electronic site-log file which is sent by ftp hourly to the PI and remote server for backup." (Miller, 2008a)

6.3 Weekly on-site equipment maintenance and QA checks

Table 6.3 weekly on-site equipment maintenance and QA checks

Weekly On-site equipment maintenance and QA checks	
Action required:	Work through operator weekly data checklist
Maintenance required:	None
Consumables required:	None
Tools required:	None

If the field operator visits the site once a week, the operator should complete an operator weekly data checklist. This checklist provides a surficial examination of the ambient mercury monitoring system to ensure that there aren't any obvious mechanical faults.

The operator weekly data checklist is found in the appendix.

Lessons learned:
"Weekly checklist items that are not automated can be logged in the electronic site log. Many of the weekly parameters can be (and should be allowed to be) monitored via data logger. These include various system temperatures." (Miller, 2008a)

6.4 Bi-Weekly equipment maintenance and QA checks

Table 6.4.1 Bi-weekly in-lab equipment maintenance and QA checks

Bi-Weekly in-lab equipment maintenance and QA checks	
Action required:	1. Maintenance
Maintenance required:	1. Prepare a new blanked GOM denuder 2. Prepare a new GL14-GL18 union [model 1130] 3. Prepare new trace-clean inlet glassware including a new frit

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	4. Prepare a new pre-purged soda lime trap
Consumables required:	1. Soda lime trap 2. Soda lime 3. Glass wool 4. 18.2 MΩ cm-resistivity water 5. Nitric acid or HCl 6. Laboratory-grade methanol 7. GOM (quartz annular) denuder 8. 2.4 M KCl 9. Source of clean air to flush denuder during pre-baking
Tools required:	1. Nitrile (or similar) gloves* 2. Teflon-coated tweezers 3. Impactor tool 4. Toothbrush 5. Lindberg/Blue M, model TF55035 clamshell tube furnace 6. An aspirator or other type of vacuum pump to draw KCl solution into the denuder

Table 6.4.2 Bi-weekly on-site equipment maintenance and QA checks

Bi-Weekly on-site equipment maintenance and QA checks	
Action required:	1. Work through operator bi-weekly data checklist 2. Maintenance
Maintenance required:	1. Install new blanked GOM denuder 2. Install trace-clean GL14-GL18 union 3. Install new trace-clean inlet glassware including a new frit 4. Install new pre-purged soda lime trap 5. Install new, pre-packed zero air filter housing in 1130 (Olson, 2008) 6. Install new, pre-packed sample line filter housing in 1130 (Olson, 2008) 7. Leak check the system by zero-air vacuum method 8. Check lamp voltage – adjust as necessary 9. Check dri-rite and replace as

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	necessary (Miller, 2008a)
Consumables required:	1. New blanked GOM denuder 2. Pre-purged soda lime trap 3. New zero air filter in 1130 4. New sample line filter in 1130 5. Dri-rite (if necessary) 6. Pre-cut saran wrap or cut-off new clean nitrile or PVC glove finger
Tools required:	1. Nitrile (or similar) gloves 2. Toothbrush 3. Multimeter for testing lamp voltage and precision 4. Flat-head screwdriver 5. Pair of adjustable wrenches

Every other week, the operator should complete an operator bi-weekly data checklist and perform all of the required scheduled maintenance listed in the bi-weekly scheduled maintenance protocol. This checklist provides a more in-depth examination of the ambient mercury monitoring system to ensure that there aren't any obvious mechanical faults. The bi-weekly scheduled maintenance protocol is detailed in such a way that an operator knows which components need to be changed out, which consumables are necessary to be replaced, and which tools are necessary to perform these actions. Nitrile, latex, vinyl, or chloroprene gloves should always be worn when touching any of the Tekran equipment.

6.4.1 Bi-weekly in-lab equipment maintenance

Prepare a new blanked GOM denuder

Cleaning previously coated denuders adapted from (Landis et al., 2002)

Step 1. Rinse the denuder with 18.2 MΩ cm-resistivity water.
Step 2. Submerge the denuder vertically by a ring stand for 24 hours with 18.2 MΩ cm-resistivity water up to the radial notches of the annulus.
Step 3. After this 24-hour rinsing, the denuder should be cleaned in the same manner as a new quartz annular denuder.

Cleaning new quartz denuders adapted from (Landis et al., 2002)

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Step 1. Rinse the denuder with 1% HCl or 10% reagent-grade nitric acid.
Step 2. Rinse the denuder with 18.2 MΩ cm-resistivity water.
Step 3. Carefully pour laboratory-grade methanol into the denuder, but not into the annulus through the vent.

Lessons learned:
"We have not cleaned ours with nitric acid…we rinse with methanol and blow them dry after they have been thoroughly soaked in DI water." (Steffen, 2008)
"Ditto, no nitric acid for me either." (Olson, 2008)

Coating the denuder adapted from (Landis et al., 2002)

Step 1. Prepare the 2.4 M concentration aqueous KCl solution by dissolving 90 grams of high-purity KCl into 18.2 MΩ cm-resistivity water to produce 500 mL of coating solution.
Step 2. The denuder should be suspended vertically by a ring stand holding the denuder inlet submerged in a beaker filled with KCl solution.
Step 3. A vacuum line (or aspirator) with a needle valve connected to the exit side of the denuder should be used to pull KCl solution into the denuder to just above the active denuder surface.
Step 4. After the KCl solution reaches just above the denuder surface, allow the KCl solution to recede down into the beaker by opening up the needle valve.
Step 5. The coating process is to be repeated twice to allow for a full coating of the denuder.
Step 6. Once the coating process is finished, remove the denuder from the ring stand and shake it to remove excess solution.
Step 7. Remove excess KCl solution from the denuder walls below the etched area by drawing up 18.2 MΩ cm-resistivity water several times up to the bottom of the etched area (Felton, 2008).
Step 8. The denuder can be further dried by blowing with zero air (Olson, 2008).

Lessons learned:

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"You have to clean the quartz section located at the bottom between the inlet and the annuli and let it dry prior to baking it. If it's not clean this changes the surface coating and the property of the denuder. Furthermore, they assure that the annuli is not plugged." (Poissant, 2008)

Baking the denuder adapted from (Landis et al., 2002)

Step 1. KCl denuders should be heated in a clamshell tube furnace (commercially available: Lindberg/Blue M, model TF55035) at 525 °C for 30 minutes while pulling mercury-free air through the denuder at a rate of 1.5 liters per minute (Landis et al., 2002; Poissant, 2008).

Step 2. Coaxial cooling fans should be used at both ends of the furnace to prevent damage to the Teflon hoses from excessive heat.

Step 3. Folded quartz fiber filters may be used to ensure a tight seal between the furnace ends and the denuder.

Prepare new trace-clean inlet and glassware including a new frit

Step 1. If the inlet and glassware has been removed from the model 1130 already, start at Step 5.

Step 2. Unbutton the external heating jacket (at the bottom of the 1130 case) on the impactor and allow it to hang down.

Step 3. Disconnect the Teflon tubing from the zero air inlet at the red nut.

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Figure 2 - Zero air inlet attachment to impactor (Steffen, 2002b)

Step 4. Loosen the red nut (GL25 union) that holds the denuder and inlet – remove this dirty glassware train.

Step 5. Separate the impactor tee from the impactor inlet and then remove the upstream tee from the impactor body. (Miller, 2008b)

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Figure 3 – Tekran® model 1130 inlet components (Tekran, 2006a)

Step 6. Remove the impactor frit using the impactor tools.
Step 7. The white impactor "OUT" tool screws into the impactor on the inlet side while the three prongs of the impactor removal tool is used to push the frit out of the impactor.

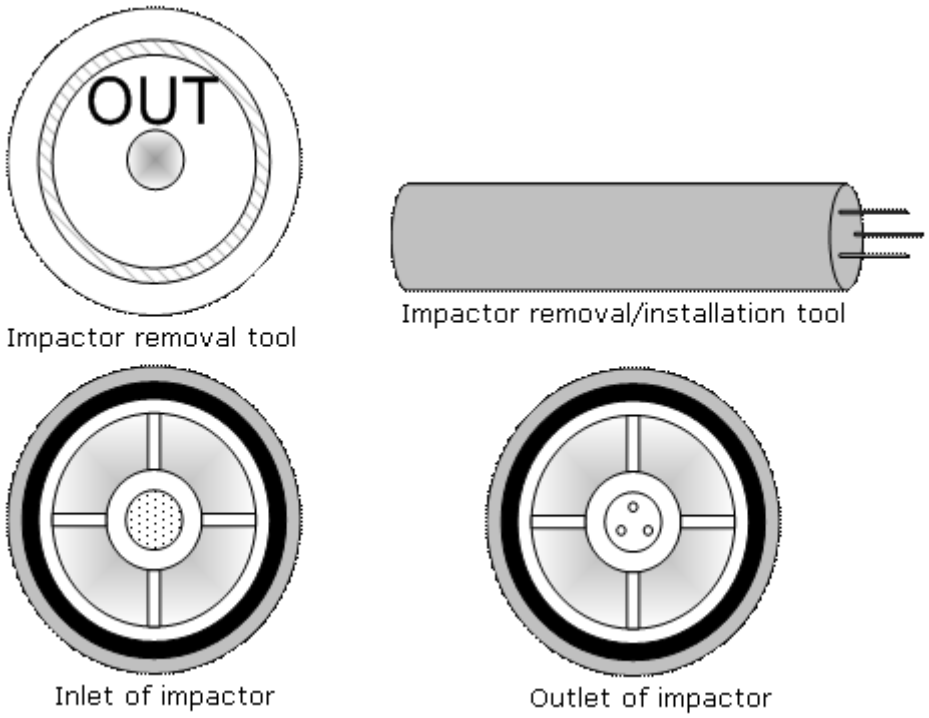

Figure 4 – Impactor "OUT" tool (ARA, 2003e)

Step 8. Wipe the inside of inlet glassware with nitrile gloved hands and long cotton swabs to remove visible dirt and insects. A [toothbrush] can be used with deionized water to clean the dirty side of the frit (Miller, 2008b). Must be careful with the use of brushes in any Teflon coated glassware and must be careful not to scratch coating (Olson, 2008).
Step 9. Flip the frit to the other side to get use out of both sides, if both sides have been used, install a new frit into the impactor (Felton, 2008; Luke, 2008; Steffen, 2008).*
Step 10. The impactor "IN" tool screws into the outlet side of the impactor.

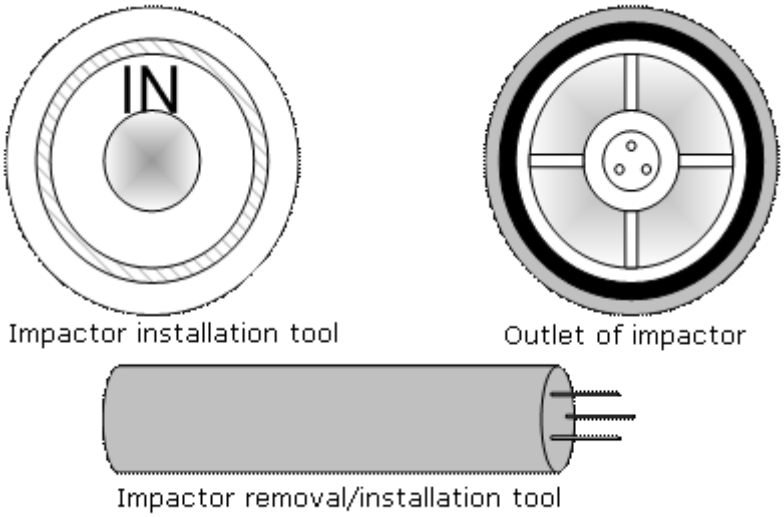

Figure 5 – Impactor "IN" tool (ARA, 2003e)

Step 11. Use the flat side of the impactor "IN" tool to push the frit into place, trying to solidly place the frit into the holder.

Step 12. With the new frit installed, place the impactor back onto the inlet. **Ensure the impactor is facing the proper direction – otherwise no flow and poor data will result** (Steffen, 2008).

Step 13. Place the new trace-clean impactor and glassware into a double-bagged ziploc bag for travel to site.

Lessons learned:
"When replacing the denuder and impact disk glassware, I connect the units together in a clean area of the lab and stored in plastic until just before installation in the 1130 sampling unit. I would think trying to put these parts together outside during the denuder-inlet change out would be asking for trouble. The units can be easily put together and checked in a clean area of the operations lab and stored in plastic until ready for installation." (Dalziel, 2008)
"It is also important to remember when connecting the impactor inlet to the impactor body (Fig. 10), not to screw this glass connector too tightly to the impactor disk, just snug is all that is required. Over tightening can dislodge the impact disk from its Teflon holder in the impactor body." (Dalziel, 2008)
"Acid rinse ALL components upstream of denuder with every denuder change, not simply wiping the glassware clean (this will not clean as well, and may damage the Teflon coating over time) -acid rinse/DI

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rinse/methanol rinse the elutriator, impactor (flip or replace frit to expose an unused face), glass tee, and Teflon union to denuder body." (Luke, 2008)
"I use DIH2O and MeOH" (Olson, 2008)

Prepare a new pre-purged soda lime trap

Figure 6 – Soda lime trap (ARA, 2003e)

Update from Tekran:
"We are about to launch an inexpensive soda lime trap that we will test, date-label and pack in batches so users can just install a new tube filled with soda lime each time they need to. You could leave these steps in the method for those that want to do their own. We'd want to add a short description of the alternative procedure when we know that." (Prestbo, 2008)

Step 1. Unscrew one of the Teflon nuts at one end of the soda lime trap and remove the glass wool from this end with tweezers.

Step 2. Empty out all of the soda lime.

Step 3. Unscrew the Teflon nut at the opposite end of the soda lime trap and remove the glass wool from this end with tweezers.

Step 4. Place the empty soda lime trap and Teflon nuts into a 1% HCl or 10% nitric acid bath for 12 hours.

Step 5. Rinse the soda lime trap 3 times with 18.2 MΩ cm-resistivity water and then use laboratory-grade methanol to facilitate drying.

Step 6. Allow to dry in a clean portion of a lab.

Step 7. Place a small piece of glass wool into one end of the soda lime trap to prevent soda lime from pouring out.

Step 8. Screw the Teflon nut at the end with the glass wool, being careful not to torque the nut so much that it deforms.

Step 9. Pour soda lime into the soda lime trap allowing enough room for glass wool to prevent soda lime from pouring out of the opposite end.

Step 10. Screw the opposite Teflon nut onto the soda lime trap, again being careful not to torque the nuts so much that they deform.

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Step 11. After packing the soda lime trap, purge with Hg-free zero air at 50 mL/min for 1 hour (Holsen & Choi, 2008).

Install new zero air filter into the zero air filter housing in the 1130

Step 1. If you have a zero air filter housing already removed from the model 1130, skip to Step 4.

Step 2. Open the 1130 case. Turn off the power so the case heater turns off. **Be careful not to burn yourself or melt tubing by contacting the case heater element.** (Miller, 2008b)

Step 3. Remove the zero air filter housing by first unscrewing the Teflon nuts attaching the housing to the Teflon tubing. **Be careful not to lose the ferules or twist the Teflon tubing when disconnecting the housing.** (Miller, 2008b)

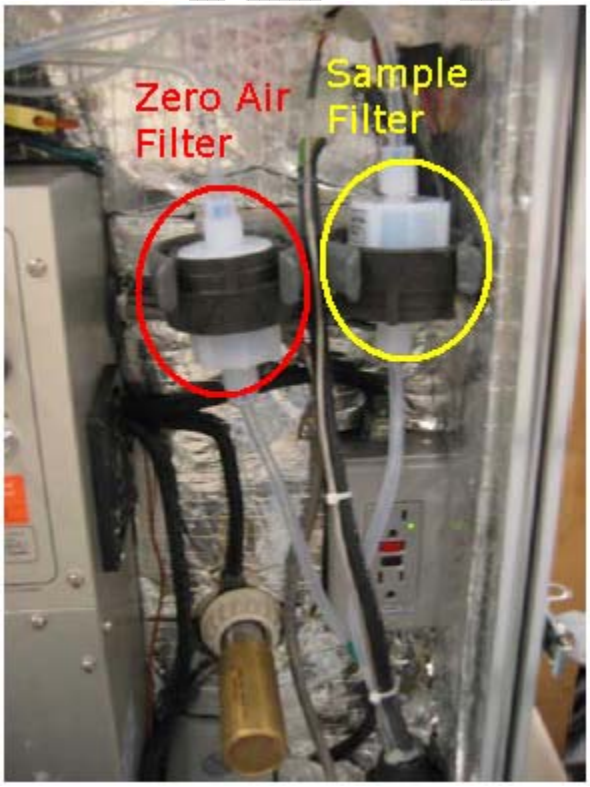

Figure 7 – Tekran® model 1130 zero air and sample filters (Steffen, 2002b)

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Step 4. With the filter housing out of the model 1130, use one of the green filter wrenches to grasp one half of the filter housing and grasp the other half of the housing with another green filter wrench.

Step 5. When the two halves of the filter housing are separated, remove the old filter.

Step 6. Using Teflon-coated tweezers, install a new 1 μm Teflon filter, ensuring that the smooth Teflon side faces up and the fibrous backing side is down.

Step 7. Close the filter housing by hand before using two green filter wrenches to seal the filter housing.

Step 8. Cap the inlet and outlet ends with plastic travel caps and store the housing in a double-bagged ziploc bag for storage and transport to the site.

Lessons learned:
"I have found it much easier when replacing the sample and zero filters in the 1130 sampling unit to have the filters preloaded in their Teflon holders and install the "loaded" filter units rather than try to load the individual filter into the holders in the outside environment." (Dalziel, 2008)
"Optionally, the filter holder can be exchanged with one that already has a clean filter installed – this is easier in windy, cold and rain/snow." (Felton, 2008)
"I like to take filters out then loosen and replace." (Olson, 2008)
"My recommendation here would be to remove the filter holder entirely and replace it with one that has a preloaded filter in it. Much easier and not fiddling with those terrible green wrenches outside." (Steffen, 2008)
"At VT99 we clean and repack the filter housings in the controlled environment of the lab (no clean hood needed) and never have contamination problems. We then swap fully loaded filter housings (clean for dirty) in the sampling head. We feel this provides for a much lower risk of contamination than the recommended approach. The steps below are modified for our method." (Miller, 2008b)

Install new sample filter into the sample air filter housing in the 1130

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Step 1. If you have a sample air filter housing already removed from the model 1130, skip to Step 4.

Step 2. Open the 1130 case. Turn off the power so the case heater turns off. **Be careful not to burn yourself or melt tubing by contacting the case heater element.** (Miller, 2008b)

Step 3. Remove the sample air filter housing by first unscrewing the Teflon nuts attaching the housing to the Teflon tubing (see Figure 7). **Be careful not to lose the ferules. Be especially careful not to twist the Teflon tubing when disconnecting the housing as this may torque the regenerable particulate filter (RPF) and break the RPF tail.** (Miller, 2008b)

Step 4. With the filter housing out of the model 1130, use one of the green filter wrenches to grasp one half of the filter housing and grasp the other half of the housing with another green filter wrench.

Step 5. When the two halves of the filter housing are separated, remove the old filter.

Step 6. Using Teflon-coated tweezers, install a new quartz fiber filter, ensuring that the smooth side faces down.

Step 7. Close the filter housing by hand before using two green filter wrenches to seal the filter housing.

Step 8. Cap the inlet and outlet ends with plastic travel caps and store the housing in a double-bagged ziploc bag for storage and transport to the site.

Step 9. Turn the power back on

Lessons learned:
"I have found it much easier when replacing the sample and zero filters in the 1130 sampling unit to have the filters preloaded in their Teflon holders and install the "loaded" filter units rather than try to load the individual filter into the holders in the outside environment." (Dalziel, 2008)
"Optionally, the filter holder can be exchanged with one that already has a clean filter installed – this is easier in windy, cold and rain/snow." (Felton, 2008)
"I like to take filters out then loosen and replace." (Olson, 2008)

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"My recommendation here would be to remove the filter holder entirely and replace it with one that has a preloaded filter in it. Much easier and not fiddling with those terrible green wrenches outside." (Steffen, 2008)
"At VT99 we clean and repack the filter housings in the controlled environment of the lab (no clean hood needed) and never have contamination problems. We then swap fully loaded filter housings (clean for dirty) in the sampling head. We feel this provides for a much lower risk of contamination than the recommended approach. The steps below are modified for our method." (Miller, 2008b)

6.4.2 Bi-weekly on-site equipment maintenance and QA checks

Install trace-clean blanked GOM denuder into the model 1130

Step 1. Check the 2537 unit's operating mode. If the 2537 is operating in Hg (0) mode (neither desorbing, nor calibrating), then depress the 'ESC' button in rapid succession, and then depress 'ESC' once more to put the 2537 into IDLE mode. If the 2537 is not in Hg (0) mode, wait until it goes into Hg (0) mode before putting it into IDLE mode. (Miller, 2008b)

Step 2. Unbutton the external heating jacket (at the bottom of the 1130 case) on the impactor and allow the jacket to hang down. Carefully remove the inlet thermocouple. (Miller, 2008b)

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Figure 8 - External heating jacket (Steffen, 2002b)

Step 3. Disconnect the Teflon tubing from the zero air inlets at the red nut, while being careful not to lose the gasket at the end of the Teflon tubing. (Miller, 2008b)

Figure 9 - Zero air inlet attachment to impactor (Steffen, 2002b)

Step 4. Loosen the red coupling nut that holds the denuder and impactor together and set the impactor aside.

Figure 10 - Red coupling nut connecting the denuder and impactor (Steffen, 2002b)

Step 5. Open the 1130 case. Turn off the power so the case heater turns off. **Be careful not to burn yourself or melt tubing by contacting the case heater element.** (Miller, 2008b)

Step 6. Loosen the GL14-GL18 union fitting that holds the denuder and regenerable particulate filter (RPF) together. When loosening the GL14-18 do not allow the RPF to turn. Hold the top of the RPF. The RPF has to be disconnected from the bracket and moved up to allow the denuder to move up enough to go over the pins (Felton, 2008; Poissant, 2008; Steffen, 2008).

Figure 11 - Red coupling nut between the denuder and RPF (ARA, 2003a)

Step 7. There are two tabs on the top of the denuder to keep it in place. To remove the denuder, carefully push up on the denuder and rotate it 90 degrees to clear the tabs. Do not let go of the denuder or it will fall to the ground and break.

Lessons learned:
"Really difficult to do it when RPF is installed, especially when the small device is installed onto the RPF tail. This is due to you pushing up on the RPF to remove the union." (Poissant, 2008)

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Figure 12 – Glass tabs on the quartz annular denuder (Tekran, 2006a)

Step 8. Carefully pull the denuder straight down and off the 1130 case.

Step 9. Install a new blanked denuder by first removing the red cap from the small end of the denuder. Use a cut off new clean nitrile, latex, or, PVC glove finger or piece of saran wrap to cover the small end of the denuder.

Step 10. Carefully push the small end of the denuder up through the 1130 case until it appears out of the top end. Push the denuder up enough to allow the tabs to come out of the rubber seal and then rotate the denuder 90 degrees. Now lower the denuder so that it rests on top of the rubber seal.

Step 11. Remove the clean glove finger, then tighten the red nut connecting the denuder and the RPF (ensuring that neither the denuder, nor the RPF rotate). **Be very careful not to push the RPF up or you will break the tail.** (Miller, 2008b)

Step 12. At some point the denuder will be up enough to allow the tabs to come out of the rubber seal. Try to rotate the denuder so the tabs catch – before you fully tighten the denuder/RPF coupling. Tighten the coupling fully and check that it is still tight on the RPF.

Lessons learned:
"Occasionally, the glass connecting tube in the coupling will lift up into mouth of the RPF as the fitting is screwed onto the denuder. If this

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happens, you will have to back everything out and remove the fitting from the mouth of the RPF." (Miller, 2008b)

Step 13. Using a clean glove finger, push the glass tube down so it seals on the gasket. Push the small (denuder end) red cap up the tube as far as it goes. Now reassemble, carefully lowering the small red cap to the denuder threads as needed.

Step 14. Close the 1130 case. Keep the power off and the heating jacket unbuttoned for installing new trace-clean inlet glassware and exchanging the sample air and zero air filters.

Step 15. Turn power back on unless proceeding with additional servicing

Install a trace-clean GL14-GL18 union

Step 1. Open the 1130 case. Turn off the power so the case heater turns off. **Be careful not to burn yourself or melt tubing by contacting the case heater element.** (Miller, 2008b)

Figure 13 – GL14-GL18 union (ARA, 2003d)

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Step 2. Loosen the old GL14-GL18 union fitting that holds the denuder and regenerable particulate filter (RPF) together. When loosening the GL14-18 do not allow the RPF to turn. Hold the top of the RPF. Do not let go of the denuder or it will fall to the ground and break.

Step 3. Rinse the GL14-18 union 3 times with 18.2 MΩ cm-resistivity water and then use laboratory-grade methanol to facilitate drying.* (If the GL14-18 union is believed to be contaminated – it may be necessary to place the GL14-18 union in a 1% HCl or 10% nitric acid bath for 12 hours. After an acid bath, rinse 3 times with 18.2 MΩ cm-resistivity water and then use laboratory-grade methanol to facilitate drying.)

Step 4. Allow to dry in a clean portion of a lab.

Step 5. Replace the old GL14-18 union fitting with a trace-clean GL14-18 union.

Step 6. Turn on the power inside the 1130 case. Close the 1130 case.

Install trace-clean inlet and glassware including a new frit adapted from (Miller, 2008b)

Step 1. The heating jacket should already be unbuttoned.

Step 2. The zero air feed line should already be disconnected. Take the end cap off of the clean denuder that has just been installed in the unit. Put it on the dirty denuder that has been removed.

Step 3. You should have a fully prepared clean inlet glassware train in a ziploc bag.

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Figure 14 – Tekran® model 1130 inlet components (Tekran, 2006a)

Step 4. Slide the zero air feed line into the upstream Tee.

Step 5. Screw the full inlet train onto the denuder mouth and tighten the GL-25 union securely. **Be very careful not to push up on the denuder or you could break the RPF tail. Be sure not to let the denuder rotate or the denuder/RPF fitting may be loosened and leak – or you could twist the RPF and break the tail. All the glassware handling in this system takes incredible care, patience, and a light touch.**

Step 6. Securely tighten the red nut connecting the zero air feed line to the upstream Tee.

Step 7. Carefully place the monitoring thermocouple into the heated boot so it will rest just inside the boot against the inlet. Secure the heated boot over the inlet glassware and fasten up.

Install new pre-purged soda lime trap

Step 1. Check the 2537 unit's operating mode.

Step 2. If the 2537 is operating in Hg (0) mode, then depress the 'ESC' button in rapid succession, then depress 'ESC' once more to put the 2537 into IDLE mode. If the 2537 is not in Hg (0) mode, wait until it goes into Hg (0) mode before putting it into IDLE mode. *

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Step 3. Unscrew Teflon end nuts from the soda lime trap.

Figure 15 – Soda lime trap (ARA, 2003e)

Step 4. Install a new pre-purged soda lime trap downstream of the sample splitting Tee and before the 2537 sample filter.* Firmly tighten (but not deforming) the Teflon end nuts with adjustable wrenches (Felton, 2008).

Lessons learned:
"Na-lime traps…I purge with Zero Hg air for 30-40 minutes just prior to installation. I use the Tekran 1100 zero air generator with DFU filter and regulator as my source of Hg free air. I also change out the quartz wool used in both ends of the trap each time new Na-lime is used. If this method is deemed suitable maybe we should include these details for the end user." (Dalziel, 2008)

Install new pre-packaged zero air filter housing in 1130

Step 1. Open the 1130 case. The power should be off, but if not, turn off the power so the case heater turns off. **Be careful not to burn yourself or melt tubing by contacting the case heater element.** (Miller, 2008b)

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Figure 16 – Inside the Tekran® model 1130 unit (ARA, 2003a)

Step 2. Remove the travel cap from the inlet side of the new zero air filter housing. Carefully loosen the Teflon nuts on the lower end of the zero air filter housing and remove this housing. Take care not to lose the ferrule. Slide the new filter housing carefully upward into the holder and connect the Teflon nuts to the inlet side of the new filter housing. Place the travel cap on the open port of the old filter housing. (Miller, 2008b)

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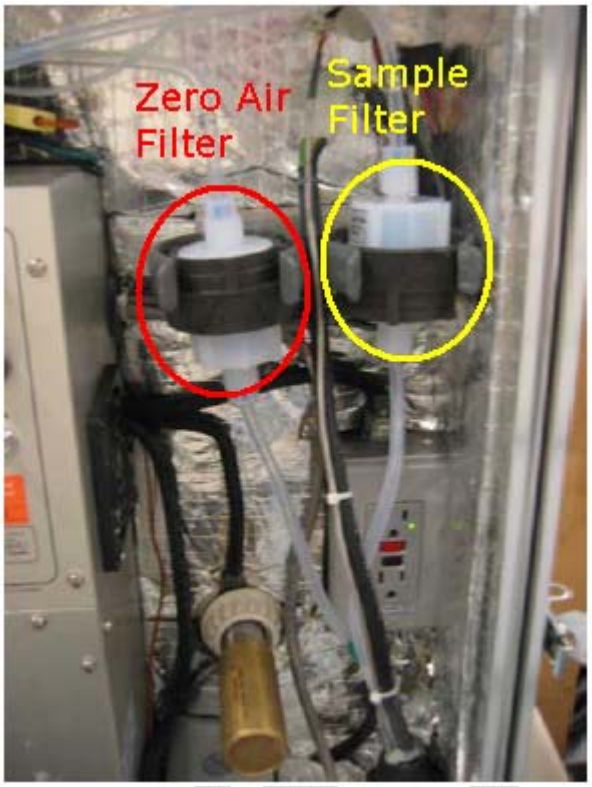

Figure 17 – Tekran® model 1130 zero air and sample filters (Steffen, 2002b)

Step 3. Remove the travel cap from the outlet of the new zero air filter housing (now sitting in the holder bracket). (Miller, 2008b)

Step 4. Remove the Teflon nuts from the base of the old sample line filter cartridge (don't lose the ferrule!). Attach to the base (outlet) of the new zero air filter housing. **Again be careful not to push the cartridge up and tweak the RPF tail.** (Miller, 2008b)

Step 5. Put the travel cap on the open port of the old zero air filter housing. (Miller, 2008b)

Step 6. Make sure no Teflon lines are near the case heater element. Make sure you haven't left anything loose inside the case. (Miller, 2008b)

Lessons learned:
"I have found it much easier when replacing the sample and zero filters in the 1130 sampling unit to have the filters preloaded in their Teflon holders and install the "loaded" filter units rather than try to

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load the individual filter into the holders in the outside environment." (Dalziel, 2008)
"Optionally, the filter holder can be exchanged with one that already has a clean filter installed – this is easier in windy, cold and rain/snow." (Felton, 2008)
"I like to take filters out then loosen and replace." (Olson, 2008)
"My recommendation here would be to remove the filter holder entirely and replace it with one that has a preloaded filter in it. Much easier and not fiddling with those terrible green wrenches outside." (Steffen, 2008)
"At VT99 we clean and repack the filter housings in the controlled environment of the lab (no clean hood needed) and never have contamination problems. We then swap fully loaded filter housings (clean for dirty) in the sampling head. We feel this provides for a much lower risk of contamination than the recommended approach. The steps below are modified for our method." (Miller, 2008b)

Install new pre-packaged sample filter housing in 1130

Step 1. Open the 1130 case. The power should be off, but if not, turn off the power so the case heater turns off. **Be careful not to burn yourself or melt tubing by contacting the case heater element.** (See Figure 17) (Miller, 2008b)

Step 2. Remove the travel cap from the outlet side of the new sample line filter housing. Carefully loosen the Teflon nuts on the upper end of the zero air filter housing and remove it. Take care not to lose the ferrule. **It is very important that the tubing connected to the filter housing does not twist or is not forced upward. The RPF may break. The best way to avoid this problem is to slowly lower the old sample line filter in the holder bracket as the quick-grip fitting is loosened.** Once the Teflon nut is loose, slide the old sample filter housing out of the holder. Slide the new filter housing carefully upward into the holder and connect the Teflon nut fitting to the inlet side of the new sample line cartridge. Slowly ease the cartridge up in the holder as you tighten the fitting, so the tail of the RPF is not flexed. Place the

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travel cap on open port of the old filter housing. See Figure 17 (Miller, 2008b)

Step 3. Remove the travel cap from the outlet of the new sample filter housing (now sitting in the holder bracket). (Miller, 2008b)

Step 4. Remove the Teflon nuts from the base of the old sample filter housing (don't lose the ferrule!). Attach to the base (outlet) of the new sample filter housing which holds quartz fiber filters. **Again be careful not to push the cartridge up and tweak the RPF tail.** (Miller, 2008b)

Step 5. Put the travel cap on the open port of the old sample filter housing. (Miller, 2008b)

Step 6. Make sure no Teflon lines are near the case heater element. Make sure you haven't left anything loose inside the case. Turn on the case power. Close the case. (Miller, 2008b)

Lessons learned:
"I have found it much easier when replacing the sample and zero filters in the 1130 sampling unit to have the filters preloaded in their Teflon holders and install the "loaded" filter units rather than try to load the individual filter into the holders in the outside environment." (Dalziel, 2008)
"Optionally, the filter holder can be exchanged with one that already has a clean filter installed – this is easier in windy, cold and rain/snow." (Felton, 2008)
"I like to take filters out then loosen and replace." (Olson, 2008)
"My recommendation here would be to remove the filter holder entirely and replace it with one that has a preloaded filter in it. Much easier and not fiddling with those terrible green wrenches outside." (Steffen, 2008)
"At VT99 we clean and repack the filter housings in the controlled environment of the lab (no clean hood needed) and never have contamination problems. We then swap fully loaded filter housings (clean for dirty) in the sampling head. We feel this provides for a much lower risk of contamination than the recommended approach. The steps below are modified for our method." (Miller, 2008b)

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Bi-weekly QA checks

Leak check the system by zero air vacuum method

Step 1. Perform the leak test only when the 2537 is operating in Hg (0) mode, otherwise wait until the 2537 goes into Hg (0) mode.

Step 2. Ensure that the 2537 has been operating for at least 15 minutes.

Step 3. Secure a zero air canister to the Tekran model 1130 impactor inlet. This will require a connecting union between the ¼" Teflon line exiting the zero air canister and the impactor inlet, which may be available through URG (Chapel Hill, NC) or Tekran. The zero air canister should scrub all Hg from the incoming air and increase the pressure drop within the entire speciation system.

Step 4. Operate the Tekran model 1130, if no Hg peak is detected, then the entire speciation system passes the leak check.

Step 5. And if the entire speciation system doesn't pass, you need to go through part by part to check where the leak is (Steffen, 2008).

*

This method should be thoroughly reviewed by mercury monitoring experts, specifically updating information regarding:

a) What is the part number for the connecting union between the impactor inlet and the zero air canister?

Lessons learned:
"URG has a connector for #30 thread to the bottom of their denuder but not to #25 thread on the Tekran style denuder – I am ordering tapered rubber stoppers for the inlet because I can't find silicone. I have asked URG for a tube connector to the impactor inlet." (Felton, 2008)

b) How should the 2537/1130 be programmed to effectively test this method?)

The zero air vacuum method discussed in this SOP allows for increasing the pressure drop while still allowing air to pass through the system.

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Check lamp voltage – adjust as needed

Lessons learned:
"Lamp driver voltage can be continuously monitored and displayed by a data logger, eliminating the need for a multimeter." (Miller, 2008a)

Procedure for auditing the UV lamp adjustment potentiometer
(ARA, 2003b; Tekran, 2006c)
(this method is an alternative to checking the analog output voltage at the back of the 2537)

Step 1. Ensure the 2537 instrument has been in RUN mode for at least 30 minutes prior to testing the lamp adjustment potentiometer voltage.

Step 2. Remove the top panel from the 2537 and locate the lamp driver board.

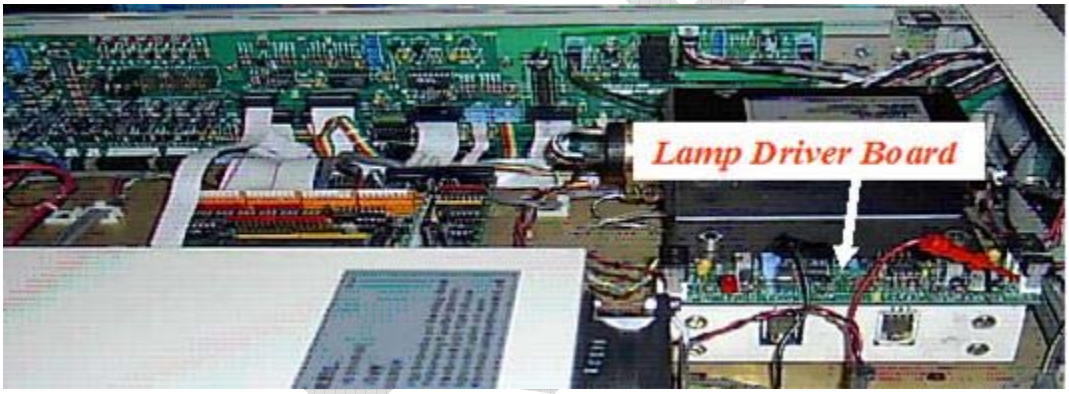

Figure 18 – Lamp driver board (ARA, 2003b)

Step 3. Locate the lamp adjustment potentiometer (on the lamp driver board) and the two test points: GND (Black) and LDR (Red).

Lessons learned:
"The LDR check point on the lamp stabilizer circuit board is not located as shown on some older Tekran models." (Dalziel, 2008)

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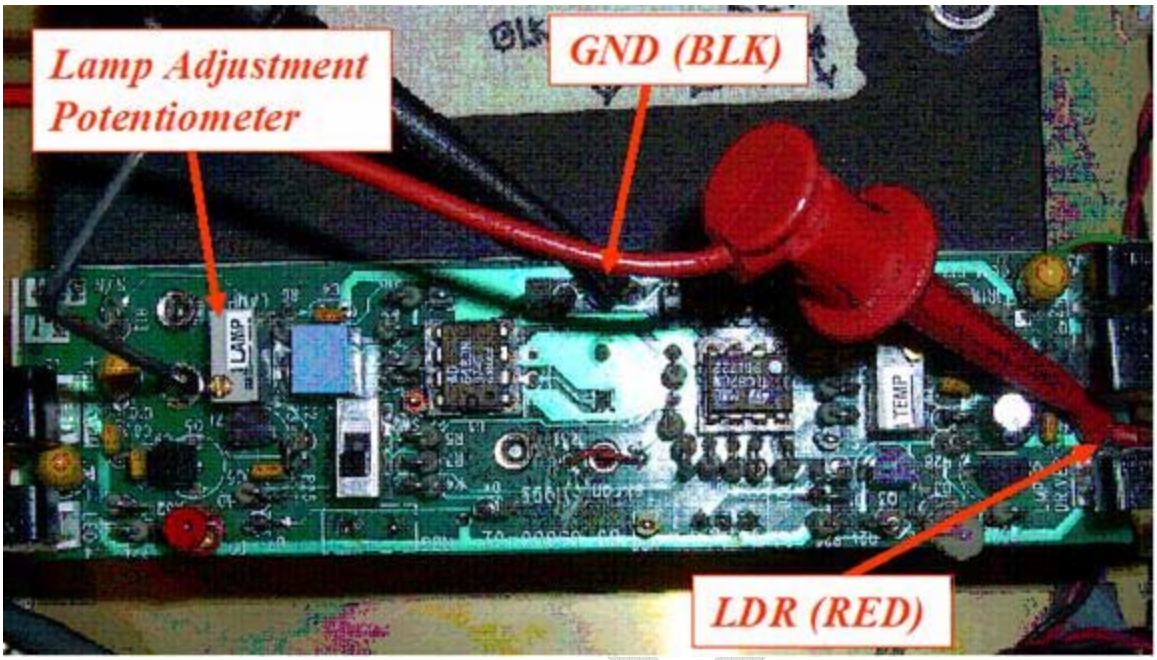

Figure 19 – Lamp adjustment potentiometer (ARA, 2003b)

Step 4. Set the multimeter tool to read DC volts and attach this multimeter to the two test points, GND and LDR, on the lamp driver board.

Step 5. The voltage on the multimeter tool should read between 9-12 VDC for older lamps and approximately 7 VDC for new lamps.

Lessons learned:
"Why does this procedure have to be performed bi-weekly? It could be more appropriate to use the analog output located at the back of the 2537A to monitor the lamp voltage." (Poissant, 2008)
"I prefer to have the LDR and GND voltage available on the rear panel. I installed 2 banana plugs just below the chart output on the instrument rear panel. That way you do not have to remove the instrument cover.
Tekran has a problem with the 2537B lamp driver. The lamp is driven near its maximum and if it is also physically optimized the lamp circuit has a problem because as it increases the voltage the lamp output decreases. Tekran said there may be a hardware fix available by the end of this week. If you have this problem, you will not be able to adjust the LDR low enough for example: (<10.5 v)" (Felton, 2008).*

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Procedure for adjusting the UV lamp adjustment potentiometer (ARA, 2003b; Tekran, 2006c)

Step 1. Ensure the 2537 instrument has been in RUN mode for at least 30 minutes prior to testing the lamp detector voltage.

Step 2. Remove the top panel from the 2537 and locate the lamp stabilizer (L/S) circuit board (see Figure 20).

Step 3. Locate the lamp adjustment potentiometer (on the lamp driver board) and the two test points: GND (Black) and LDR (Red).

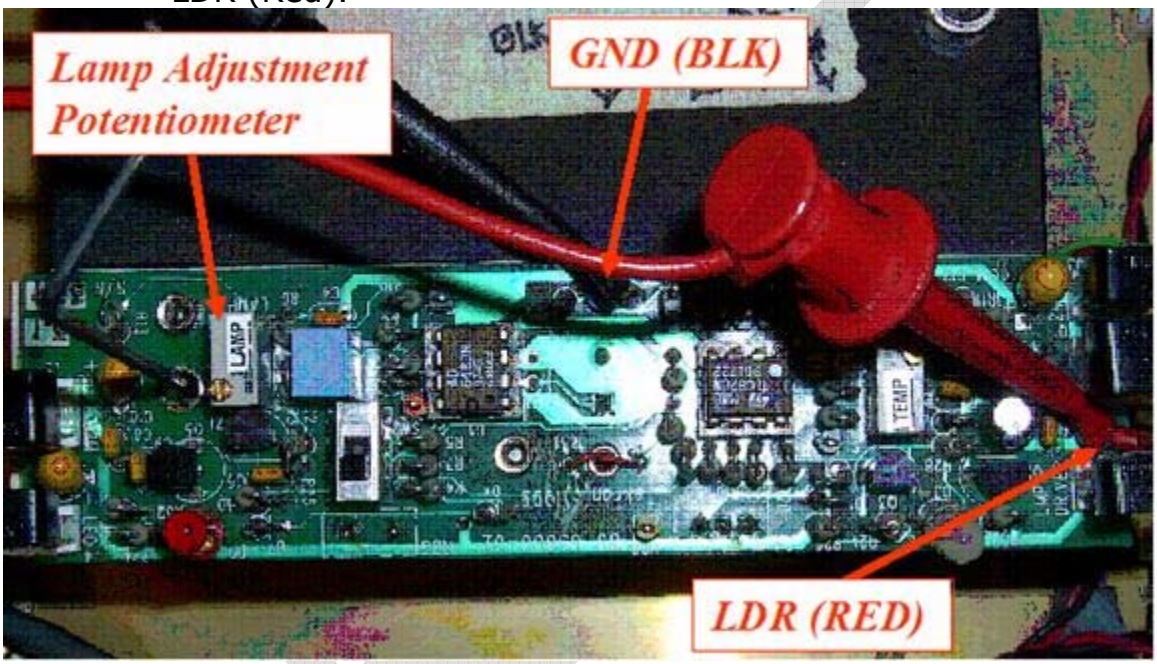

Figure 20 – Lamp adjustment potentiometer (ARA, 2003b)

Step 4. Set the multimeter tool to read DC volts and attach this multimeter to the two test points, GND and LDR, on the lamp driver board.

Step 5. Use a precision flat-head screwdriver to adjust the lamp voltage by turning the lamp adjustment potentiometer. For new lamps the voltage should be set to 7 VDC. For older lamps the voltage should be set to 9 VDC.

Step 6. Check and adjust the front panel OFFSET control if required to ensure that the baseline is positive. (The instrument must continue to be in RUN mode to do this.) Change the LED display on the 2537 to RUN.CURRENT by using the < and > buttons. The detector voltage (displayed on the right-hand side of the LED display) should be between 0.09 and 0.11 VDC (Holsen & Choi,

2008; Olson, 2008), if the voltage is not within this range, then the front panel OFFSET adjustment is necessary.* "Don't make adjustments when the instrument indicates "HEATING", "PEAKDLY", or "Baseline" cycles, as you won't be setting on the baseline, you will be setting on a peak."* (Miller, 2008b; Olson, 2008)

Step 7. Unlock the OFFSET adjustment knob (located on the front face of the 2537 unit – see Figure 21) and turn the knob clockwise to increase the UV lamp detector voltage.

Figure 21 – Tekran® ambient Hg vapor analyzer – the red circle indicates the offset adjustment knob (Tekran, 2006c)

Lessons learned:
"I have found when required to adjust the baseline voltage, I find it easier to keep the Offset adjustment knob locked while adjusting the voltage. This makes it much easier to make gradual and fine adjustments to the baseline voltage." (Dalziel, 2008)
"I have noted on occasion with new and older Tekrans, adjusting the lamp voltage with the lamp intensity adjustment screw at times does not produce a voltage effect to the lamp…and by toggling the Lamp Mode Switch from Auto to Fixed and back to Auto will solve this issue." (Dalziel, 2008)

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6.5 Monthly equipment maintenance and QA checks

Table 6.5.1 Monthly in-lab equipment maintenance

Monthly in-lab equipment maintenance	
Action required:	1. Maintenance
Maintenance required:	1. Install new sample filter for 2537 (Holsen & Choi, 2008) 2. Install new zero air filter for 2537 (Holsen & Choi, 2008)
Consumables required:	1. New zero air filter for 2537 2. New sample filter for 2537 3. HCl or nitric acid* 4. 18.2 MΩ cm-resistivity water 5. Laboratory-grade methanol
Tools required:	1. Nitrile (or similar) gloves 2. Teflon-coated tweezers 3. Two green filter wrenches 4. Pair of adjustable wrenches

Table 6.5.2 Monthly on-site equipment maintenance and QA checks

Monthly on-site equipment maintenance and QA checks	
Action required:	1. Work through operator monthly data checklist 2. Maintenance
Maintenance required:	1. Confirm inlet volumetric flow rate is between 8.0 and 11.0 L/min*
Consumables required:	1. None
Tools required:	1. Nitrile (or similar) gloves 2. Pair of adjustable wrenches 3. Two green filter wrenches 4. Bios®, Gilibrator®, or equivalent mass flowmeter

Every month, the operator should complete an operator monthly data checklist and perform all of the required scheduled maintenance listed in the monthly scheduled maintenance protocol. This checklist provides a more in-depth examination of the ambient mercury monitoring system to ensure that there aren't any obvious mechanical faults. The

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monthly scheduled maintenance protocol is detailed in such a way that an operator knows which components need to be changed out, which consumables are necessary to be replaced, and which tools are necessary to perform these actions. Nitrile, latex, vinyl, or chloroprene gloves should always be worn when touching any of the Tekran equipment.

6.5.1 Monthly in-lab equipment maintenance

Install new 2537 Teflon sample filter and clean housing (ARA, 2003d)

Step 1. Turn off the 2537 to ensure that the fan is not blowing dust/carbon from the pump brushes. (Miller, 2008a)
Step 2. Identify the "Sample Inlet" filter pack housing.
Step 3. Pull up on the sample filter pack housing to remove it from the green holders. Next loosen the Teflon nuts from the inlet and outlet of the filter housing with an adjustable wrench.
Step 4. With one of the green filter wrenches, grasp the inlet of the filter housing (top, clear portion) and loosen the filter housing with another green filter wrench.

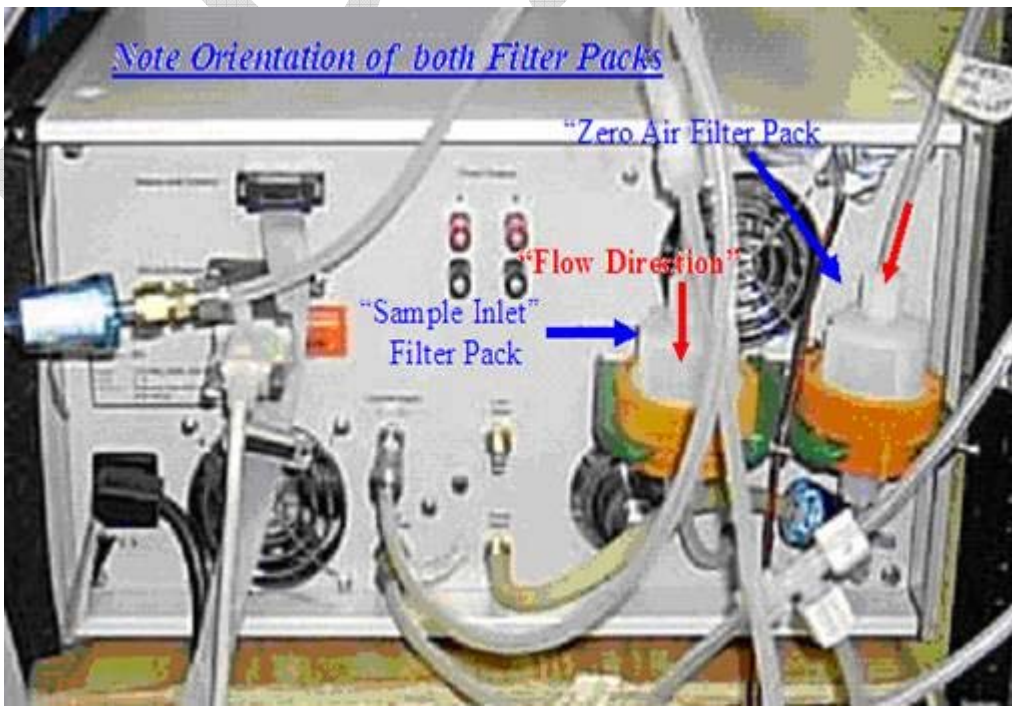

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Figure 22 – Rear face of the Tekran 2537 ambient mercury vapor analyzer (ARA, 2003d)

Step 5. When the two halves of the filter housing are separated, remove the old filter.

Step 6. Clean the filter housing by rinsing with 1% HCl or 10% reagent-grade nitric acid, then rinse with 18.2 MΩ cm-resistivity water, and then lastly rinse with laboratory-grade methanol and allow to fully dry (Landis et al., 2002).

Step 7. Using Teflon-coated tweezers, install a new 1 μm Teflon filter, ensuring that the smooth Teflon side faces up and the fibrous backing side is down.

Step 8. Close the filter housing by hand before using green filter wrenches to seal the filter housing. Tighten the Teflon tubing loosened during the filter change out.

Lessons learned:
"I replace the whole cartridge with a new one and would never change it in place due to potential contamination. I like to have spare equipment that I slap in place then re-clean the used stuff and vacuum seal the parts." (Olson, 2008)
"Changing the filter in the shelter is OK. But please turn off the instrument first so the fan is not blowing dust/ carbon from the pump brushes around the area as you change the filter. A better solution is to have pre-packed filter housings in the lab and change the whole housing out." (Miller, 2008a)

*

Install new 2537 zero air filter and clean housing (ARA, 2003c)

Step 1. Identify the "Zero Air Inlet" filter pack housing.*

Step 2. Pull up on the sample filter pack housing to remove it from the green holders. Next loosen the Teflon nuts from the inlet and outlet of the filter housing with an adjustable wrench.

Step 3. With one of the green filter wrenches, grasp the inlet of the filter housing (top, clear portion) and loosen the filter housing with another green filter wrench (see Figure 22)

Step 4. When the two halves of the filter housing are separated, remove the old filter.

Step 5. Clean the filter housing by rinsing with 1% HCl or 10% reagent-grade nitric acid, then rinse with 18.2 MΩ cm-

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resistivity water, and then lastly rinse with laboratory-grade methanol and allow to fully dry (Landis et al., 2002).

Step 6. Using Teflon-coated tweezers, install a new 1 μm Teflon filter, ensuring that the smooth Teflon side faces up and the fibrous backing side is down.

Step 7. Close the filter housing by hand before using green filter wrenches to seal the filter housing. Tighten the Teflon tubing loosened during the filter change out.

Step 8. Turn the 2537 back on.

Lessons learned:
"I replace the whole cartridge with a new one and would never change it in place due to potential contamination. I like to have spare equipment that I slap in place then re-clean the used stuff and vacuum seal the parts." (Olson, 2008)
"Changing the filter in the shelter is OK. But please turn off the instrument first so the fan is not blowing dust/ carbon from the pump brushes around the area as you change the filter. A better solution is to have pre-packed filter housings in the lab and change the whole housing out." (Miller, 2008a)

*

Monthly QA checks

Confirm inlet volumetric flow rate is between 8.0 – 11.0 L/min (Miller, 2008a; Tekran, 2006a)

Step 1. Check the 2537 unit's operating mode.

Step 2. If the 2537 is operating in Hg (0) mode, then depress the 'ESC' button in rapid succession, then depress 'ESC' once more to put the 2537 into IDLE mode. If the 2537 is not in Hg (0) mode, wait until it goes into Hg (0) mode before putting it into IDLE mode (Miller, 2008b).*

Step 3. Connect the mass flowmeter (e.g., Gilibrator®, Bios®, etc) to the impactor inlet fitting of the Tekran® model 1130.

Lessons learned:
"Gil. flow meter is not easy to use outside due to weather conditions: wind, rain, and solar radiation." (Poissant, 2008)

Step 4. Flip the PUMP FLOW switch to the 'SAMPLE' position.

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Step 5. Flip the ZERO AIR switch to the 'OFF' position.
Step 6. Turn on the "PUMP" switch on the 1130 pump module (Miller, 2008b).

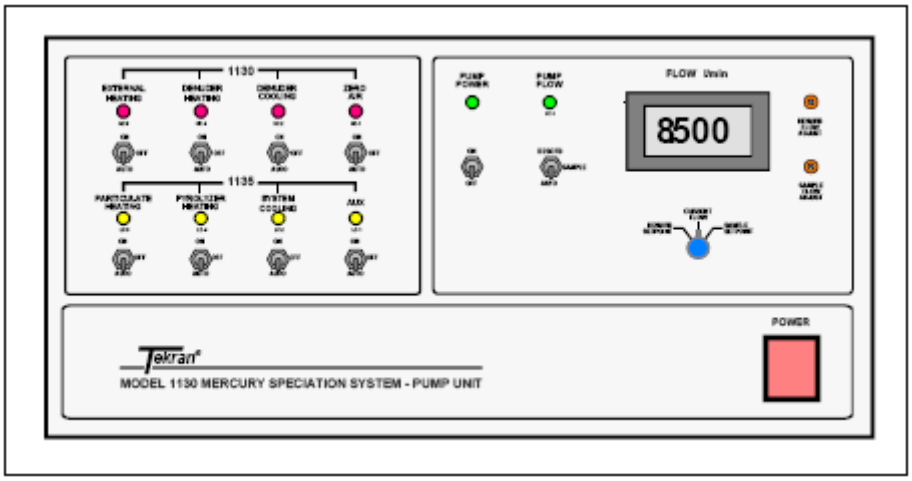

Figure 23 – Tekran model 1130 pump unit (Tekran, 2006a)

Step 7. Record the mass flowmeter's gauge reading and enter it into the site-operations log.
Step 8. Confirm inlet volumetric flow rate is between 8.0 – 11.0 L/min (Miller, 2008b).

Lessons learned:
"To be complete or if out of spec, record the temp and pressure" (Felton, 2008).

Step 9. If the volumetric flow rate is not between 8.0 – 11.0 L/min, adjust the sample flow set point potentiometer accordingly (Miller, 2008b).
Step 10. IMPORTANT - Reset the scale factors to adjust for the new flow setting (see Table A-2 in the Appendix).

Lessons learned:
"You might be able to locate your flow meter inside the shelter and use the dedicated zero (leak-check) line connected to the inlet for the flow rate test. I want to try this, as we cannot successfully use our flow meter outside during harsh winter conditions. If this doesn't work, then we might need to relax the requirement for system flow-rate check during harsh/winter weather." (Miller, 2008a)*

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6.6 Four to six-week equipment maintenance and QA checks

Table 6.6.1 Four to six-week on-site equipment maintenance and QA checks

Six-week in-lab equipment maintenance	
Action required:	1. Maintenance
Maintenance required:	1. Clean and repack the RPF [model 1135] 2. Trace-clean the RPF 3/8" to ¼" Teflon elbow fitting and Teflon tubing (Luke, 2008)
Consumables required:	1. New 20.6 μm quartz filter for RPF 2. Quartz wool 3. Laboratory-grade methanol 4. 18.2 MΩ cm-resistivity water (DIW)
Tools required:	1. Nitrile (or similar) gloves 2. Lindberg/Blue M, model TF55035 clamshell tube furnace 3. Nichrome wire removal tool 4. Teflon-coated tweezers

Table 6.6.2 Six-week on-site equipment maintenance and QA checks

Six-week on-site equipment maintenance and QA checks	
Action required:	1. Work through operator six-week data checklist 2. Maintenance
Maintenance required:	1. Install new blanked regenerable particulate filter assembly [model 1135] 2. Install trace-clean RPF 3/8" to ¼" Teflon elbow fitting and Teflon tubing [model 1135] (Luke, 2008) 3. Rinse Teflon tubing extending from soda-lime trap to 2537 sample filter with DIW and methanol
Consumables required:	1. Nitrile (or similar) gloves 2. New 20.6 μm quartz filter for RPF

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	3. Quartz wool 4. Laboratory-grade methanol
Tools required:	1. Nichrome wire removal tool

Nitrile, latex, vinyl, or chloroprene gloves should always be worn when touching any of the Tekran equipment.

Clean and repack the regenerable particulate filter (RPF)
adapted from (Miller, 2008b; Tekran, 2006b)

Step 1. If the RPF is already removed from the model 1135, skip to Step 11.
Step 2. Always replace the quartz annular denuder before replacing the RPF.
Step 3. Check the 2537 unit's operating mode.
Step 4. If the 2537 is operating in Hg (0) mode, then depress the 'ESC' button in rapid succession, then depress 'ESC' once more to put the 2537 into IDLE mode. If the 2537 is not in Hg (0) mode, wait until it goes into Hg (0) mode before putting it into IDLE mode.
Step 5. Open the 1130 front face and the top door on the 1135.
Step 6. Inside the 1130, remove the inlet line from the sample filter and make sure it's free. (Olson, 2008)
Step 7. If you use the RPF support bracket, loosen the bracket thumb screws and remove the RPF support bracket.*
Step 8. "With the RPF in place, hold down bracket for the extension tube on the RPF **must be set loose** before any adjustment to the fitting holding the RPF to the denuder GL14-GL18 union." (Dalziel, 2008)

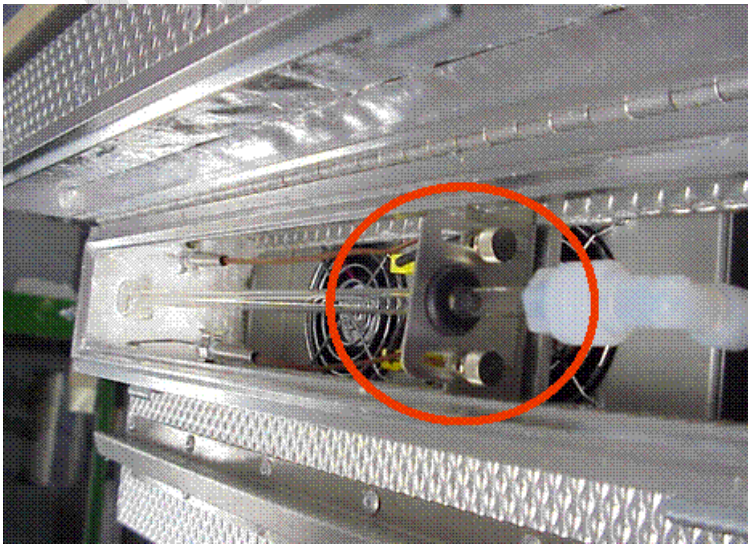

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Figure 24 – RPF mounting bracket screws and Teflon elbow (ARA, 2003c)

Step 9. Loosen the red nut (on the left side at the top of the 1130 case) that holds the denuder and regenerable particulate filter (RPF) together.

Figure 25 - Red coupling nut between the denuder and RPF (ARA, 2003a)

Step 10. Pull the RPF and sample line slowly and carefully up and out of the 1135 case.

Step 11. Use the nichrome wire removal tool to remove the quartz wool plug from the RPF. Set the old quartz wool plug aside to use as a size reference for its replacement.

Step 12. Rinse the RPF with deionized water by filling from each end, swirling, and then dumping it out.

Step 13. Rinse the RPF with methanol by filling from each end, swirling, and then dumping it out.*

Step 14. If any visible residue remains in the tail, attach moist (or methanol moistened) quartz wool to wire tool. Carefully swab the tail. Do not leave any quartz wool remaining

Step 15. Rinse the RPF with deionized water by filling from each end, swirling, and then dumping it out.

Step 16. Install the nut and ferrule for the elbow fitting on the tail of the RPF. Wrap 2-3 thicknesses of Teflon tape covering ½ inch from the end of the tail.

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Step 17. Test fit the elbow fitting. Adjust the Teflon tape as needed to get a secure, snug fit. This is a prime location for leaks. There WILL be a leak if you do not use Teflon tape.

Step 18. Attach the elbow fitting and Teflon tubing. You will use it to connect to the mercury-free air source.

Step 19. Dry the RPF by purging with mercury-free air for 1 hour.

Step 20. Gently bend a quartz filter disk and fit it through the opening. Slide the curled disk down the tube. When the filter reaches the frit, use the tool to unfold the filter. Insure the filter is centered and flat on the frit. Ensure the filter seals over the whole frit.

Step 21. Pack a piece of quartz wool (refer to the old piece for size) so it sits on top of the filter. Pack this reasonably firmly, but not too firmly.

Step 22. Install the main body of the RPF into the Lindberg/Blue M, model TF55035 clamshell tube furnace. Attach the mercury-free air source to tubing attached to the tail. Bake at 800°C for 30 minutes while pulling mercury-free air through the RPF tail at a rate of 1.5 liters per minute.*

Step 23. When cool, cap the large end with the yellow or red end cap. Remove the elbow fitting (leaving the nut and ferrule on the tail). Wrap the tail end tightly with saran-wrap. Store in the protective case.

Step 24. Wrap the ends of the elbow-tubing piece with saran wrap and store in a clean ziploc bag. Label the bag "clean RPF tail fittings". Place this bag in the 1135 case with the RPF.

Step 25. Should the need arise for extreme cleaning or changing of the quartz chips in the pyrolyzer section of the RPF, refer to the Tekran manual.

Lessons learned:
"Might as well change the Teflon fitting and the tubing on the tail whenever you change the RPF as these do get scummy and should be cleaned." (Miller, 2008a)

Install a new blanked regenerable particulate filter (RPF) (ARA, 2003c; Steffen, 2002b; Tekran, 2006b)

Step 1. Always replace the quartz annular denuder before replacing the RPF.

Step 2. Check the 2537 unit's operating mode.

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Step 3. If the 2537 is operating in Hg (0) mode, then depress the 'ESC' button in rapid succession, then depress 'ESC' once more to put the 2537 into IDLE mode. If the 2537 is not in Hg (0) mode, wait until it goes into Hg (0) mode before putting it into IDLE mode.

Step 4. Open the 1130 front face and the top door on the 1135.

Step 5. Inside the 1130, remove the inlet line from the sample filter and make sure it's free. (Olson, 2008)

Step 6. If you use the RPF support bracket, loosen the bracket thumb screws and remove the RPF support bracket.

Step 7. "With the RPF in place, hold down bracket for the extension tube on the RPF **must be set loose** before any adjustment to the fitting holding the RPF to the denuder GL14-GL18 union." (Dalziel, 2008)

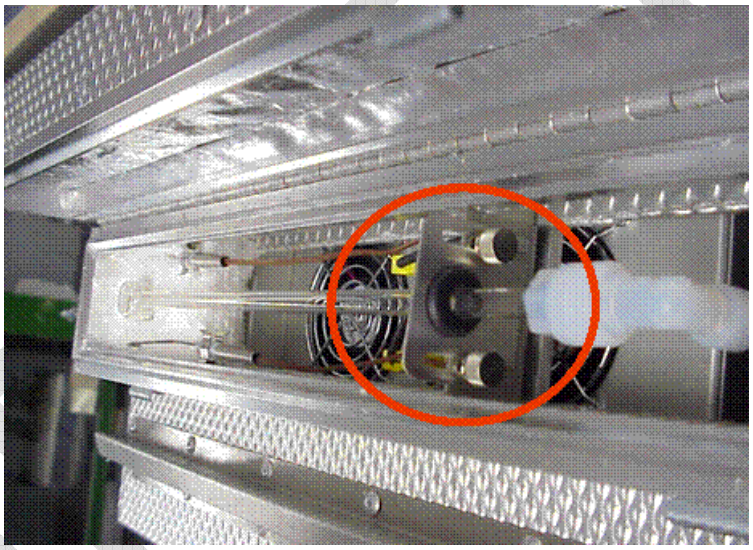

Figure 26 – RPF mounting bracket screws and Teflon elbow (ARA, 2003c)

Step 8. Loosen the red nut (on the left side at the top of the 1130 case) that holds the denuder and regenerable particulate filter (RPF) together.

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Figure 27 - Red coupling nut between the denuder and RPF (ARA, 2003a)

Step 9. Pull the RPF and inlet line slowly and carefully up and out of the 1135 case.

Step 10. Attach an inlet line to a new RPF and install by slowly and carefully pushing a new RPF down into the 1135 case.*

Step 11. Tighten the red nut (on the left side at the top of the 1130 case) that holds the denuder and regenerable particulate filter (RPF) together.

Step 12. If you use the RPF support bracket, replace the RPF support bracket onto the RPF and tighten the support bracket thumb screws.

Step 13. Close the 1135 case door.

Lessons learned:
"This is one of the most common places for the system to leak. I do not tighten this elbow in place, rather I remove the nut and tubing from the top (inlet) of the 1130 sample filter. Then I remove the tubing with the RPF. This allows me to rinse the tubing, tighten it onto the new RPF and install it as one unit. If you try and suggest people tighten this in place, they'll either break them or they'll leak." (Olson, 2008)
Regarding the RPF support bracket, "I don't use this." (Olson, 2008)

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"Might as well change the Teflon fitting and the tubing on the tail whenever you change the RPF as these do get scummy and should be cleaned." (Miller, 2008a)

Rinse the Teflon tubing extending from soda-lime trap to 2537 sample filter with DIW

Step 1. Check the 2537 unit's operating mode.
Step 2. If the 2537 is operating in Hg (0) mode, then depress the 'ESC' button in rapid succession, then depress 'ESC' once more to put the 2537 into IDLE mode. If the 2537 is not in Hg (0) mode, wait until it goes into Hg (0) mode before putting it into IDLE mode.
Step 3. Disconnect the Teflon tubing between the soda-lime trap to the 2537 sample filter.
Step 4. Rinse the Teflon tubing 3 times with 18.2 MΩ cm-resistivity water.
Step 5. Rinse the Teflon tubing with laboratory-grade methanol and allow to fully dry.
Step 6. Reattach the Teflon tubing and put the 2537 back to RUN mode.

6.7 Quarterly on-site equipment maintenance and QA checks

Table 6.7 Quarterly on-site equipment maintenance and QA checks

Quarterly on-site equipment maintenance and QA checks	
Action required:	1. Work through operator quarterly data checklist 2. Maintenance
Maintenance required:	1. Audit the mass flowmeter in 2537 2. Audit the mass flowmeter in the 1130 pump module 3. Verify the 2537 internal permeation tube emission rate by syringe injection (by site auditor) 4. Check the nichrome gold cartridge heating coils [model 2537] 5. Check and synchronize the Tekran clock to NIST source time (Miller, 2008a)
Consumables	1. Tekran 2537 Septa

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required:	
Tools required:	1. Nitrile (or similar) gloves 2. Bios®, Gilibrator®, or equivalent mass flowmeter 3. Tekran 2505 Mercury Vapor Calibration Unit 4. Thermocouple or multimeter to test the nichrome gold cartridge heating coils

Nitrile, latex, vinyl, or chloroprene gloves should always be worn when touching any of the Tekran equipment.

Audit the mass flowmeter in the 2537 (Tekran, 2006a)

Step 1. Check the 2537 unit's operating mode.
Step 2. If the 2537 is operating in Hg (0) mode, then depress the 'ESC' button in rapid succession, then depress 'ESC' once more to put the 2537 into IDLE mode. If the 2537 is not in Hg (0) mode, wait until it goes into Hg (0) mode before putting it into IDLE mode.
Step 3. Connect the mass flowmeter (e.g., Gilibrator®, Bios®, etc) to the SAMPLE fitting of the 2537 unit.
Step 4. Record the mass flowmeter's gauge reading.

Lessons learned:
"We use a Sierra Instruments mass flow meter to check the 2537A sample flow and the 1130 pump unit sample flow. Our Sierra instruments mass flow meter is calibrated to different standard conditions than the Tekran mass flow meters/controllers (it gets calibrated annually by Sierra), so I made a little Excel spreadsheet that uses the ideal gas law to convert the volume flow digital outputs to mass flow so I can compare the Tekran instruments against my flow meter. A Bios or something that has temperature and pressure correction built in could also check the Tekran mass flows. Measuring volumetric flow through the sample inlet would need to be done with a Bios or Gillibrator volumetric flow meter." (Lyman, 2008)

Audit the mass flowmeter in the 1130 pump module (Tekran, 2006a)

Step 1. Check the 2537 unit's operating mode.

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Step 2. If the 2537 is operating in Hg (0) mode, then depress the 'ESC' button in rapid succession, then depress 'ESC' once more to put the 2537 into IDLE mode. If the 2537 is not in Hg (0) mode, wait until it goes into Hg (0) mode before putting it into IDLE mode.

Step 3. Connect the mass flowmeter (e.g., Gilibrator®, Bios®, etc) to the VENT fitting of the 1130 pump module.

Step 4. Flip the PUMP FLOW switch to the 'DESORB' position.

Step 5. Flip the ZERO AIR switch to the 'ON' position.

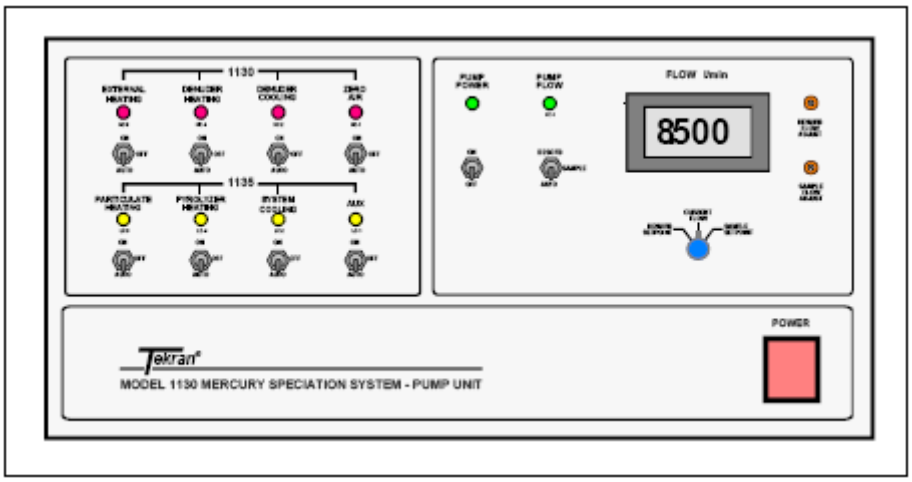

Figure 28 – Tekran model 1130 pump unit (Tekran, 2006a)

Step 6. Record the mass flowmeter's gauge reading.

Verify the 2537 internal permeation tube emission rate by syringe injection (INL, 2006; Steffen, 2002a)
(Additional expert mercury monitoring feedback in this issue is necessary to complete this section)

Manual, syringe injections are made with a microliter capacity syringe (e.g., 25 μL Hamilton® digital syringe) drawing pure gaseous elemental mercury from a Tekran® model 2505 mercury vapor primary calibration unit.

Lessons learned:
"Take Calibrator to site and plug it in on trip before audit is to be performed if possible." (Felton, 2008)

"My procedure has not changed from the SOP for CAMNet to which you refer here. We do change the perm rate when it's different by more than 5%." (Steffen, 2008)
"I have a very [specific] approach to verifying the perm tube. I've learned this by trial and error (mainly error). There a lot of things that can go wrong during this procedure and it can contaminate the system for days. Some points below:
Clean 2505 inlet, change septum, allow to stabilize. Heat/clean syringe needle Have 2537 stop mark etched in needle Change 2537 septum after 2 injections and at end of procedure. I've found that injections (2537) during sampling cycle (1130P @ 9 LPM) the system is under vacuum thus the recoveries are a few % higher. Once again, you need to be really [specific] and know what you're doing not to [mess] things up."* (Olson, 2008)

Check the nichrome gold cartridge heating coils by color or temperature

(Additional expert mercury monitoring feedback in this issue is recommended to complete this section)

Lessons learned:
"That's pretty much what we do… if they are more than a year old we usually change them for good measure anyway." (Steffen, 2008)

*

This can be performed in a number of ways:

1) Using a thermocouple to record the heating coils' temperature

Lessons learned:
"How? I do this with a dummy trap in the lab but in a 2537? [This is difficult] – remove traps etc…" (Olson, 2008)

2) Using a multimeter to test the heater coils' voltage

*

3) Observing the heater coil turn red when heating up

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Lessons learned:
Regarding option #3, observing the heater coil turn red when heating up; "That's what I do" (Olson, 2008)
"At VT99 we are currently using method 3 or method 1 as needed. This is not a necessary quarterly step in our view. Adequate QA function and detection of problems with the heaters is achieved by simply monitoring the SPAN area counts for each channel. The SPAN area counts should be relatively stable. If there is a sudden or continued downward drift in the area count, this signals that heaters may be the problem. When such a signal is observed we would observe the heaters or replace them as part of our trouble shooting steps. If the SPAN area counts are stable, there is no problem with the heaters. So this test is unnecessary on a regular basis. We replace heater coils once per year, which prevents this type of problem." (Miller, 2008b)

Check and synchronize the Tekran clock to the NIST Time Standard

Step 1. Double click the clock on the bottom right hand side of your computer screen. A new window entitled "Date and Time Properties" appears, click on the "Internet time" tab and then click on "Update now" – ensure that "Automatically synchronize with an Internet time server" has a check mark filled in. This will ensure that your computer's clock is synchronized (if an internet connection is not available at your site, a GPS unit will provide accurate time).

Step 2. On the model 2537, navigate through the user screens if needed to display the Tekran Time.

Step 3. Note the time difference between the Tekran and the computer clock (set to NIST time) and record this difference in the site operations log.

Step 4. Idle the 2537A and navigate to the SETUP → CLK → SET TIME screen.

Step 5. Keeping in mind that the NIST time display may be in DAYLIGHT SAVINGS TIME (when appropriate), note the time of the upcoming hour and minute **in eastern**

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standard time (as appropriate to your site) that will occur at the top of the next minute. Example, if the current NIST time is 13:22:07, then the next "top of the minute" would be 13:23:00. If the NIST source is displaying in DAYLIGHT TIME, then subtract one hour from the displayed hour.

Step 6. Enter this 4-digit time value into the Tekran – **but don't hit enter yet**. Following the above example, you would be entering 1323 into the Tekran. Note you need to have at least 15-20 seconds before the top of the next minute to have enough time to complete this step.

Step 7. Watching the NIST time display on the computer, count down the seconds to the top of the minute "55, 56, 57, …". When the count reaches "59", hit the ENTER key on the Tekran. The Tekran is now synchronized to NIST Time.

6.8 Six month on-site equipment maintenance and QA checks

Table 6.8 Six month on-site equipment maintenance and QA checks

Six month on-site equipment maintenance and QA checks	
Action required:	1. Work through operator six month data checklist 2. Maintenance
Maintenance required:	1. Rinse or install new, trace-clean Teflon tubing at key locations in the 1130 pump module and/or prior to the heated line (Miller, 2008a) 2. Change both of the 1130 pump unit zero air carbon canisters and DFU filters 3. Monitor the instrument shelter air for possible indoor Hg sources (Miller, 2008a; Steffen, 2008)
Consumables required:	1. A pair of zero air carbon canisters and DFU filters 2. Teflon tubing

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Tools required:	1. Nitrile (or similar) gloves 2. Pair of adjustable wrenches 3. Snips or scissors to cut wire-ties 4. Kimwipes

Nitrile, latex, vinyl, or chloroprene gloves should always be worn when touching any of the Tekran equipment.

Rinse or install new, trace-clean Teflon tubing at key locations in the 1130 pump module and/or prior to the heated line (Miller, 2008a)

Step 1. Turn off the Tekran model 1130 pump unit.
Step 2. Remove the top cover from the 1130 pump unit.
Step 3. Visually inspect the Teflon tubing inside the 1130 pump unit. If any tubing looks dirty, replace it or rinse it with 18.2 MΩ cm-resistivity water, then rinse with laboratory-grade methanol to assist drying.
Step 4. Replace the top cover on the 1130 pump unit.
Step 5. Repeat the visual inspection for Teflon tubing prior to the heated line.

Change both of the 1130 pump unit zero air carbon canisters and DFU filters

Step 1. Turn off the Tekran model 1130 pump unit.
Step 2. Remove the top cover from the 1130 pump unit.
Step 3. Cut the wire-ties holding the carbon cartridges in place.
Step 4. Use adjustable wrenches to loosen the nuts at the ends of each of the zero air carbon canisters.
Step 5. Then loosen the nuts connecting the DFU filters to the Teflon tubing.
Step 6. Completely remove the zero air carbon canisters and DFU filters from the Tekran model 1130 pump unit.
Step 7. Wipe up the carbon dust from the inside of the case using a damp Kimwipe. The carbon dust comes from the wear of the pump brushes. Dry the case with a dry Kimwipe. Change your gloves.
Step 8. If there is visible carbon deposit in the tubing, change the tubing and nylon fittings.
Step 9. Install new 1130 pump unit zero air carbon canisters and DFU filters.
Step 10. Hand-tighten the end nuts of each of the DFU filters and zero air carbon canisters.

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Step 11. Tighten the end nuts of each of the DFU filters and zero air carbon canisters with adjustable wrenches.
Step 12. Secure the canisters with wire-ties.
Step 13. Replace the cover and restore power to the pump module.

Lessons learned:
"Clean the carbon dust out of the 1130 box while the cartridges are out. Use a damp kimwipe. Clean or change the tubing." (Miller, 2008a)

Monitor the instrument shelter air – check for possible indoor Hg sources (Miller, 2008a; Steffen, 2008) – see Section 4.2.5.1

Step 1. Disconnect the 2537 sample line from the sample 1130 & 1135 train.
Step 2. Operate the 2537 in RUN mode and observe the Hg (0) values – record any irregularities.
Step 3. Reconnect the 2537 sample line to the 1130 & 1135 train.

Lessons Learned:
"What we have done in the past is to use the 2537 to test the indoor air because we decide to move to a site. We run it for a while at different spots inside and out. Testing the air coming around doors and windows from the outside in order to not have the indoor air contaminate the outdoor air. For RGM/PHg contamination …you'd have to run it the same way I'd imagine." (Steffen, 2008)

6.9 Annual on-site equipment maintenance and QA checks

Table 6.9 Annual on-site equipment maintenance and QA checks

Annual on-site equipment maintenance and QA checks	
Action required:	1. Work through operator annual data checklist 2. Maintenance
Maintenance required:	1. Replace the nichrome gold cartridge heating coils [model 2537] 2. Install new 2537 zero air canister and DFU filter 3. Rinse or install new Teflon tubing at key locations between the 2537 and 1130 including the heated line

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	4. Replace GL14-GL18 union fitting between denuder and RPF [model 1130] 5. Verify the 2537 internal mercury permeation tube emission rate by independent QA audit technician 6. Service the 1102 dryer or other zero air system (Felton, 2008) 7. Replace 1130 diaphragm and brushes [1130 pump module] (Olson, 2008)
Consumables required:	1. Nichrome gold cartridge heating coils [model 2537] 2. Zero air canister and DFU filter [model 2537] 3. Teflon $^{3}/_{8}$" to ¼" reducing union fitting on the end of the RPF tail [model 1135] 4. Teflon ¼" tubing – between 2537 and 1130 5. GL14-GL18 union fitting between denuder and RPF [model 1130] 6. 1130 pump diaphragm and brushes
Tools required:	1. Nitrile (or similar) gloves 2. Pair of adjustable wrenches 3. Two pieces of 5" long Teflon ¼" tubing or stainless steel 4. Flat-head screwdriver 5. Phillips screwdriver 6. Pliers

Nitrile, latex, vinyl, or chloroprene gloves should always be worn when touching any of the Tekran equipment.

Lessons learned:
Regarding the nichrome gold cartridge heating coils, "I've never had these go bad – yet. It's the 1135 Heater that puke all the time." (Olson, 2008)

Replace the nichrome gold cartridge heating coils (Tekran, 2006c)

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This method is thoroughly detailed in the Tekran® model 2537 user's manual.

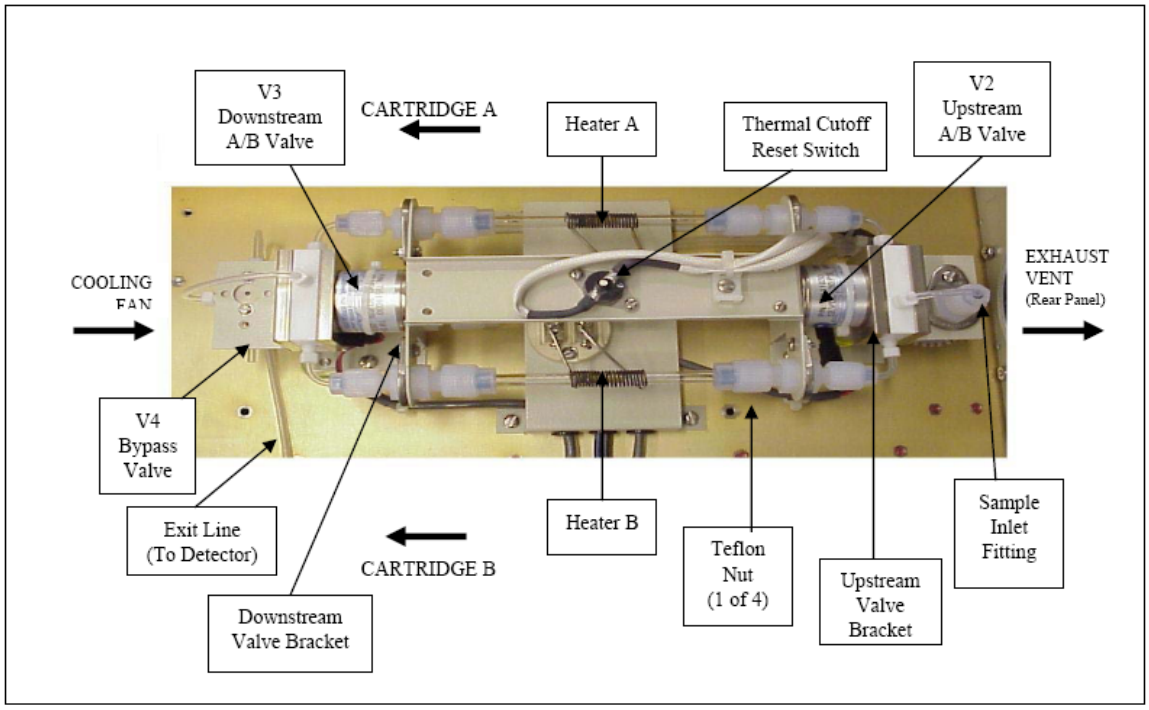

Figure 29 – Valve assembly within the Tekran® model 2537 (Tekran, 2006c)

Replacing the nichrome gold cartridge heating coils can be performed by following the Tekran® user's manual (Tekran, 2006c):

"**Installation Procedure**

Current heaters are wound more tightly than original heaters, allowing faster heat transfer into the cartridge. ***This tighter fit requires extra caution to prevent cartridge breakage !***

1) Turn off and unplug instrument. Remove top cover and valve assembly cover.
2) Remove both cartridges as per instructions in your User Manual. If the old heaters are tight, use a counter-clockwise rotation to assist removal of the cartridges from the heaters. (This direction of rotation serves to temporarily unwind (relax) the heater.)
3) Remove the two screws in the ceramic terminal block that secure each heater. Remove old heaters.
4) Thread the two 1/4" tubes into the new heaters. These tubes will be used to help align the new heaters. ***DO NOT use glass cartridges for this purpose. They will break***.

5) Attach the new heaters, taking care to align the leads the same as the pair just removed. Tighten the ceramic block mounting screws tightly. Use pliers to bend the heater leads so that the tubes are aligned with the rear valve assembly fittings and can slide into these fittings without undue lateral force. Spread heaters coils slightly to ensure that adjacent turns do not short together.
6) Temporarily attach the front valve assembly to the two tubes. Continue using pliers to adjust the heater leads so that the heaters are aligned with the front and rear assemblies. This will minimize sideways forces on the cartridges.
7) Remove the tubes. Reinstall your cartridges. ***Gently*** screw them into the heaters using a counter-clockwise rotation. Install the front (downstream) valve assembly. If steps **4** through **6** above were properly done, there should be very little lateral stress imposed on the cartridges during this operation.
8) Tighten all fittings. Apply power to the instrument and start **RUN** mode. Check that the heaters are operating properly. (They should glow red towards the end of each heating operation.)* Check for cold spots which indicate that adjacent coils are touching. If so, wait until the heater cools, then use a small screwdriver to separate the shorted turns.
9) Reinstall all covers. Let the instrument run for several hours to allow it to condition." (Tekran, 2006c)

Install new 2537 zero air canister and DFU filter

Step 1. Check the 2537 unit's operating mode.
Step 2. If the 2537 is operating in Hg (0) mode, then depress the 'ESC' button in rapid succession, then depress 'ESC' once more to put the 2537 into IDLE mode. If the 2537 is not in Hg (0) mode, wait until it goes into Hg (0) mode before putting it into IDLE mode.
Step 3. Use adjustable wrenches to loosen the nuts at the ends of each of the zero air carbon canisters.
Step 4. Then loosen the nuts connecting the DFU filters to the Teflon tubing.
Step 5. Install new zero air carbon canisters and DFU filters.
Step 6. Hand-tighten the end nuts of each of the DFU filters and zero air carbon canisters.
Step 7. Tighten the end nuts of each of the DFU filters and zero air carbon canisters with adjustable wrenches.

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Rinse or install new Teflon tubing at key locations between the 2537 and 1130 in the heat line adapted from (Miller, 2008b) (further feedback on this issue is encouraged)

Step 1. Inspect the Teflon tubing ends of the heated line between the 2537 and 1130 units. Trim back the ends only if needed to solve a leak problem.

Step 2. Replace other Teflon tubing in the system that is in poor condition due to age and normal wear.

Step 3. **Disconnect the heated sample line from the sample line filter in the 1130 sampling head and from the inlet of the soda-lime trap.** Rinse the heated sample line once with deionized water**. Make sure you have a suitable receptacle to catch the rinse as it comes through the line.** Two people are almost essential for this operation. Do not rinse the zero air line unless you have an obvious contamination problem (e.g. iodine spewed from the iodized activated-carbon cartridges).

Step 4. Only if the sample line is judged to be contaminated rinse the sample line with methanol.

Step 5. Ensure all liquid has been drained from the sample line.

Step 6. Dry the sample line by plumbing the zero air line into the sample line and running mercury-free air through the line for an hour. Some moisture may be ejected from the line initially, so be sure you still have a catch vessel at the outlet.

Step 7. Reconnect all lines.

*

Lessons learned:
"I clean this along with heated sample line annually" (Olson, 2008).
"If the flushes are good, you don't expect a contamination problem in the sampling line. You could use 10% HCl for one week in the tube to remove contamination, followed by Milli-Q water rinse" (Poissant, 2008).
"We have only done this once in 5 years and it's not part of our procedure. The main reason for me is that I need to be able to take the line down in a time when it's not totally frozen and I don't have access to the site during those times of the year. So, that may just be my problem…I'd like to hear from others the effectiveness of this. Depending on the site location this could be a total pain in the butt.

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But then I think I probably have one of the more challenging sites (the high Arctic) and so I am always thinking in those terms." (Steffen, 2008)

"This service is best and most efficiently performed prior to a bi-weekly denuder change with additional quarterly maintenance. The sample line should be cleaned prior to changing the denuder/1130 filters and the 2537A inlet soda lime trap. The sample line should also be cleaned prior to changing filters on the back of the 2537A. This service item may not be necessary in all years. The site-PI will decide if this service item is required in any given year. The rational for this decision will be recorded in the site operations log. This service item may be performed "as needed" to deal with any potential line contamination problem that might arise." (Miller, 2008b)

Replace the GL14-GL18 union fitting between the denuder and RPF

Step 1. Check the 2537 unit's operating mode. If the 2537 is operating in Hg (0) mode (neither desorbing, nor calibrating), then depress the 'ESC' button in rapid succession, and then depress 'ESC' once more to put the 2537 into IDLE mode. If the 2537 is not in Hg (0) mode, wait until it goes into Hg (0) mode before putting it into IDLE mode (Miller, 2008b).

Step 2. Open the 1130 case. Turn off the power so the case heater turns off. **Be careful not to burn yourself or melt tubing by contacting the case heater element** (Miller, 2008b).

Step 3. Loosen the GL14-GL18 union fitting that holds the denuder and regenerable particulate filter (RPF) together. When loosening the GL14-18 do not allow the RPF to turn. Hold the top of the RPF. The RPF has to be disconnected from the bracket and moved up to allow the denuder to move up enough to go over the pins (Felton, 2008; Poissant, 2008; Steffen, 2008).

Step 4. Remove the old GL14-GL18 union fitting and replace with a new GL14-18 union fitting.

Step 5. Turn on the power in the model 1130 and close the 1130 case door.

Lessons learned:

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"Might want to replace the GL14-GL18 fitting (or gaskets) quarterly or every 6 months as this is a common leak location." (Miller, 2008a)

*

Verify the 2537 internal permeation tube emission rate by independent QA audit technician
(Feedback from many different stakeholders should weigh in on the issue of whether a single network-wide site liaison/QA audit technician is necessary and what roles this person would fulfill – there seems to be interest in this)

Lessons learned:
"It could be important to certify the Hg source once a year by an external source like NIST. Audit on site is difficult to set and really expensive." (Poissant, 2008)
"I think that this is a terrific idea!! We did this for CAMNet and found that the syringes were the biggest source of error between sites so best if the person brings their own syringe and compares it to that used at the site. I can't recall how effective it was to bring the cal unit from site to site …I'll have to reread the audit report. In principle I think this is a MUST!" (Steffen, 2008)

There was discussion of a site liaison/QA audit technician at the Atmospheric Mercury Best Practices and SOP Workshop held by NADP in Chicago, IL on Oct 3-4, 2007 (NADP, 2007).

Maintenance on the 1102 or other zero air system (Felton, 2008) (further discussion is encouraged)

Replace the 1130 pump diaphragm and brushes (Olson, 2008) (further discussion is encouraged)

6.10 As-needed on-site equipment maintenance and QA checks

Table 6.10 As-needed on-site equipment maintenance and QA checks

As-needed on-site equipment maintenance and QA checks	
Action required:	1. Work through operator "As-needed" data checklist 2. Maintenance
Maintenance	1. Maintain the 2537 pump with needed

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required:	new parts dependent on model type (KNF UN89 or KNF N79) 2. Install new match-pair pure gold cartridges within the 2537 3. Clean or install new 2537 Teflon valves 4. Replace/clean quartz fluorescence cell 5. Replace the 2537 lamp due to age and poor performance
Consumables required:	1. New pure gold cartridges for the 2537 2. New Teflon valves for the 2537 3. New fluorescence cell for the 2537 4. New UV lamp for the 2537
Tools required:	1. Nitrile (or similar) gloves 2. Adjustable wrench 3. Two pieces of 5" long Teflon ¼" tubing or stainless steel 4. Flat-head screwdriver 5. Phillips screwdriver 6. Pliers 7. Allen wrenches (Felton, 2008)

Nitrile, latex, vinyl, or chloroprene gloves should always be worn when touching any of the Tekran equipment.

Maintain the 2537 pump with needed new parts dependent on model type (KNF UN89 or KNF N79)
(further discussion is encouraged)

Install new match-pair pure gold cartridges within the 2537

This method is thoroughly detailed in the Tekran® model 2537 user's manual (Tekran, 2006c).

"Cartridge Removal and Replacement

Under normal conditions, the cartridges should have an indefinite lifetime. If improper or unbalanced cartridge operation is suspected, cleaning or replacement may be required. Note that cartridges are

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usually replaced in matched pairs. Figure 29 shows the valve assembly.

1) Turn off and unplug the instrument. Remove the top cover.
2) Remove the four screws that hold the valve assembly cover. Two are located at the rear of the assembly, and two at the front. Disconnect the cartridge cooling fan power connector. Pressing the release latch will allow the connectors to be separated. Remove the valve assembly cover.
3) Remove the four screws holding the bracket containing the high temperature cutoff switch. This bracket straddles the top of the upstream (rear) and downstream (front) valve assemblies. It is not necessary to disconnect the wires attached to this bracket. It is sufficient to simply move the bracket to one side. A slot screwdriver is required for removal.
4) Loosen the four Teflon nuts holding the cartridges in place. Allow the nuts and ferrules to slide loosely along the cartridge tubes.
5) Loosen the front (downstream) valve bracket mounting screws. Remove these 4 screws.
6) Gently pull the loose valve assembly towards the front of the instrument until the front of the cartridges are clear of the fittings. Lift and tilt the front assembly until the fittings do not obstruct the cartridges.
7) Mark the front ends and relative positions of the cartridges. Then remove the cartridges, sliding them forward and out of their heater coils. Note the order and orientation of the nuts, the (black) gripper and the (white) ferrules on the fittings when removing them!
8) Either obtain new cartridges or recondition the existing cartridges using the procedures described below.
9) Slip the new/reconditioned cartridges through the heating coils, taking care to maintain their original orientation. Slip the Teflon nuts and ferrules over the rear and front quartz tubes. Ensure that the various component parts of the fittings are in the correct order when being reinstalled! Install the new cartridges and heaters.

Caution: The cartridges are fragile. Use care when reconnecting them.

Note: The cartridges are not reversible! The end with the glass orifice should always be downstream (towards the front of the instrument).

10) If necessary, centre the heating coils over the gold adsorbent slug in each cartridge. Gently flex the heating coils and heater power leads to accomplish this.

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***Caution: Ensure that adjacent turns of the heater coils do not touch one another. This will result in a short circuit that* will damage the heater and the drive electronics.**

11) Position the front valve assembly and tighten the mounting screws. Tighten the four 1/4" Teflon nuts hand tight. Tighten an additional 1/3 turn using a wrench.

Caution: Do not over tighten these fittings. Teflon fittings are very easy to strip.

12) Reinstall the temperature cutoff switch bracket across the tops of the large solenoid valves.
13) Run the instrument for a few cycles to ensure proper heater operation. Each heater should glow red by the end of the heating time.
14) Always perform a **Leak Check** of the **A** and **B** cartridges after replacing cartridges.
15) Replace the valve assembly cover. Reconnect the fan and replace and tighten the thumb screws.
16) Replace the top cover." (Tekran, 2006c)

Clean or install new 2537 Teflon valves

(Additional expert mercury monitoring feedback in this issue is recommended) (also described in the 2537A Tekran operating manual (Poissant, 2008))

Lessons learned:
Clean the valves with, "10% nitric acid, DI water, methanol, and let them dry" (Holsen & Choi, 2008).
"We don't clean them we have just replaced them as required" (Steffen, 2008).
"You need to be careful with these valves, they're PFA into FEP which is really soft material. Do not ever use a wire to clean. Back flush with DIW and MeOH only. I do this in place but wouldn't recommend that as water and electronics do not mix. No I haven't learned that the hard way, that's why I'm still doing them in place." (Olson, 2008)

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"It seems likely based on recent experience that valves will need to be changed annually for instruments in continuous operation." (Miller, 2008a)

Replace / clean quartz fluorescence cell

(Additional expert mercury monitoring feedback in this issue is recommended)

Lessons learned:
"10% nitric acid, DI water, methanol, and let them dry" (Holsen & Choi, 2008).
"I assume you mean the cuvette. We have generally followed the Tekran procedure to clean the cells but in all honesty – at the site I would recommend putting a new one in and take the old one back to the lab for cleaning and testing…no need to waste time on site." (Steffen, 2008)

*

Replace the 2537 lamp due to age and poor performance

This method is thoroughly detailed in the Tekran model 2537 user's manual (Tekran, 2006c).

"1) Turn off the instrument. Remove the top and bottom covers. The instrument should be placed on its side with both the top and bottom of the instrument accessible. Although this is no longer applicable for the 2537B (Felton, 2008).

2) On the top of the instrument, loosen the set screw (1/16" Hex drive) holding the lamp in place. This screw is located on the top of the lamp housing and is accessible through a hole in the lamp stabilizer circuit board. Gently pull the lamp from the housing until it is free. Feed the lamp and cable backwards under and between the detection cell rubber isolating standoffs until the entire cable is free. The cable is routed beneath the baseplate through the cutout located at the front right corner of the plate.

*

3) On the underside of the instrument, locate the lamp driver module. This is the small black plastic case. Locate and disconnect the six pin rectangular lamp connector. Although this is no longer applicable for the 2537B (Felton, 2008).

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4) Feed the old lamp downwards through the base plate cutout until it is free of the instrument. Discard the old lamp.
5) Route the new lamp (**Tekran Part No: 90-25180-01**) upwards through the base plate cutout. Feed the lamp and cable under the cell, between the rubber isolating standoffs. Place the lamp into the detector cell housing. Ensure that there is enough free cable to allow future removal and repositioning of the lamp.

***Note**:* Do not allow your fingers to contact the lamp. If this is not possible, use methanol to remove any oils or other residue from the lamp envelope.

6) Route the lamp cable to the lamp driver module. Connect the cable to the module.
7) Replace the bottom cover and place instrument upright.
8) Perform the **Lamp Physical Optimization** procedure below." (Tekran, 2006c)
*

Lessons learned:
"Note: Lamp needs to be optimized and then de-tuned to provide enough Dout signal." (Felton, 2008)
"Never discard old Hg lamp in normal garbage. Special regulation about hazardous materials." (Poissant, 2008)

6.11 Audit Schedule

(Expert mercury monitoring feedback in this issue is necessary)

"The biweekly, quarterly and annual procedures cover the audit unless you need an external audit." (Felton, 2008)

6.11.1 Quarterly

"It would be tough for one person to handle quarterly audit visits." (Olson, 2008)

6.11.2 Annually

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Lessons learned:
"Semi Annual spiking? Annually: Perm source check/adjustment Flow checks, 2537, 1130P zero and sample mode 2537 and 1130 P annual service – on site training" (Olson, 2008).
"I would say one initial audit for all sites than the work it so that each site is audited each 2 years. You can go from site to site within the 2 years so not all sites are audited within the same year but still get them done." (Steffen, 2008)

6.12 Soda Lime Trap and Air Drying

6.12.1 Soda lime

(Additional expert mercury monitoring feedback in this issue is recommended)

Lessons learned:
"Soda lime is easily contaminated. One supplier (auditor) of packed, pre-purged soda lime traps that have been tested and vacuum sealed would be useful." (Olson, 2008)
"I look for comments on this as well. My experience has been 4-8 mesh. Do not bake it ahead of time and don't use the indicating stuff." (Steffen, 2008)

The soda lime trap was discussed at the Atmospheric Mercury Best Practices and SOP Workshop held by NADP in Chicago, IL on Oct 3-4, 2007 (NADP, 2007). The following is a summary of this discussion:

"**TOPIC 5: Soda Lime (SL) Trap.** The goal of this topic was to learn about current practices and then have a plan for moving forward regarding soda lime use. This topic has some relevance to Topic 6 "Zero Air System" which will be dealt with separately. Several important comments were made about SL, they are:
1) Historical Information:
a. SL was chosen early on because it had been very well characterized in the mercury analytical realm and had already been proven to scrub acid gases and halide compounds while still passing elemental mercury quantitatively.

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b. SL use has been shown to prevent gold-trap passivation due to the release of deleterious compounds co-captured or formed from the heating of the denuder and RPF. No passivation is observed in locations as diverse as Detroit, Chicago, Okinawa and Everglades when using SL. Gold traps have lasted from 1.5 to 2 years with this protective SL trap installed.

Lessons learned:
Regarding the gold traps lasting from 1.5 to 2 years, "Unfortunately I have not had such benefits…" (Steffen, 2008).

c. Without SL, gold cartridge passivation may occur even if the zero air system is modified to be very dry and lacking any halide release (see Topic 6 below). Thus, it is critical that we develop a standard SL trap and protocol for use that works throughout the ambient mercury network.

*

2) Tekran is willing to provide SL traps that conform to the strict preparation, packing and date tracking requirements as defined by the user community. The SL traps will be provided at low cost and available without delay via Tekran or NADP.

Lessons learned:
"Good idea!!! My experience shows though that the ones from Tekran are too long and shorter ones, like what Matt recommends, work much better. No clue as to why ☺" (Steffen, 2008).

3) SL management and observations

a. It should be noted that passivation of gold cartridges is not always related to the absence of a SL trap. For example, making certain the nichrome wire heating system is functioning properly to burn off (clean) the gold cartridges each 5-minute sample is important to avoid gold cartridge passivation.

b. Proper storage seems to be an important factor. The SL must stay dry. The SL must not be allowed to absorb mercury from the air in the storage location.

c. SL should be changed out weekly or possibly every other week since adsorption of water and CO2 will transform it to other compounds – it will eventually turn into Ca(OH)2 or CaCO3 and no longer be soda lime. Removing water from the zero air may also improve SL longevity.

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d. Exposure of SL to high levels of halides (e.g. in mercury + halide rate experiments) has been shown to ruin the SL ability to pass elemental mercury quantitatively.
e. Teflon tubes holding SL should be pre-cleaned in acid, rinsed, dried and packed as needed. Teflon tubes are tossed after one use.

Lessons learned:
"We've never done that – just pull the tubing from the package and fill it up. Maybe this can explain why my gold traps don't last…not that I think so." (Steffen, 2008)

f. Recommend keeping SL in a desiccated box, mercury free air
g. Baked quartz wool was recommended over glass wool.
h. SL Brand: No consensus, but suggest using Mallinckrodt AR 7337 non-indicating, 4-8 mesh (Note Mallinckrodt and JTBaker merged).
i. Most users employ a SL trap and the trap is kept at room temperature.

SL Consensus: In the near term, all users in the network will use SL following a standard protocol most closely resembling the one used in Landis et al., 2002 for type, packing, pre-purge and change frequency. The performance of the SL traps should be recorded and shared (ideally in a user forum). It was recommended that one entity should produce the SL traps for consistency (individual users can still make their own if desired). Tekran has offered to follow the set protocol, including pre-purge, made to order, fresh SL, air-tight seal, documented SL age and "use-by" time stamp. Tekran will offer a very low-cost tube-only replacement (on-site compression fittings can may be cleaned and re-used)."(NADP, 2007)

Lessons learned:
"Do not see any reason to toss Teflon tubes for soda lime after each use. We routinely clean and reuse Teflon filter housings in the system. This seems wasteful and onerous and is not in our budget. We will continue to clean and reuse soda lime Teflon tubes until Tekran is able to provide economical disposable (or recyclable) units. Note suggested soda lime part number is only available in 15 kg buckets. Not practical for each site to obtain. This should be centralized network function to provide pre-purged soda lime traps." (Miller, 2008a)

6.12.2 Air Drying Unit

Tekran (Toronto, ON) Model 1102 Air Drying Unit

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(Additional expert mercury monitoring feedback in this issue is recommended)

Lessons learned:
"These units need to be looked at further. I've had several problems with zero air cans going bad after a month with 1102 drier installed. Need to determine if the cycle/regeneration set times are sufficient." (Olson, 2008)

The air drying unit was discussed at the Atmospheric Mercury Best Practices and SOP Workshop held by NADP in Chicago, IL on Oct 3-4, 2007 (NADP, 2007). The following is a summary of this discussion:

"**TOPIC 6: Zero Air System:** There was a good bit of conversation surrounding the Tekran 1130 pump module, 1102 air dryer and zero air canisters which make up the "Zero Air System". There was a high level of consensus that the proper operation and maintenance of the zero air system is critical for continuous, high quality mercury speciation measurements. A summary of the conversation and action items are listed below.

1) Maintaining very dry zero air has been shown to improve the performance of the Tekran Speciation System. It is presumed that providing dry air to the 1130 pump module prevents the release of halogen compounds from the zero air canisters which may adsorb on the soda lime trap or the gold cartridges to cause temporary and transitory low biased elemental mercury values. (Experiment: when passivation occurs after a denuder desorption cycle, disconnect the soda lime trap and see if the Tekran recovers immediately – some have observed this effect).

2) The addition of the Tekran 1102 air dryer has improved overall performance in the majority of uses as documented in the questionnaire. However, additional drying after the Tekran 1102 has been added by many users with even greater overall performance. Typically the additional drying agent is drierite or similar. Although some have tried Nafion tubes or external compressors to provide dry air as worthy alternatives.

Lessons learned:
"We hook up two drierite columns between 1130 pump unit and air dryer" (Holsen & Choi, 2008).

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"In NY we have found that 1 drierite column can be saturated after 2 weeks when installed between the 1102 and the 1130. The second column remained blue." (Felton, 2008)

3) According to the questionnaire responses, most users do not change their zero air canisters on a set schedule. However some respondents maintain that frequent changing improves performance, especially with respect to observed passivation. We agreed that the zero air canisters must be changed at least every 6 months.

4) The use of an activated carbon instead of iodinated carbon in the second stage zero air canister was postulated as a possible improvement to avoid the release of halogen compounds. Tekran briefly offered these canisters, but learned that they did not work as well. Several scientists offered to order activated carbon canisters and try them in different ways. Post meeting note: Tekran has installed an activated carbon canister on their system in Toronto and found again that it did not provide mercury free air and may actually be releasing mercury.

Lessons learned:

"I ordered AC cartridges and installed them on the outlet of the 1130P zero air feed line, downstream of the can was a DFU. In the 1130P were Iodinated cans. I saw nothing but zeros indicating no contamination from the non-I cans. This may be a way to reduce the Iodine into the system but when they go, all cans would be shot and potentially the internal tubing excessively contaminated with I. Still need some work in this area." (Olson, 2008)

5) The questionnaire documented that the Tekran 1102 air drying unit has been found to be helpful. In comparison to other options considered for water removal, the 1102 is compact, quiet, modular and simple to operate. However, in some extreme cases the 1102 has been found to under perform. It has been suggested that the cycling time of the 1102 could be adjusted for better performance. It was also suggested that the molecular sieve in the 1102 will eventually need replacing. It was also suggested that the addition of a small pump to supply forced air during the heating cycle of the 1102 would help drive collected water off of the molecular sieve to improve performance.

Based on the workshop conversation the following set of solutions is recommended for improved zero air system performance. Prestbo will coordinate the following:

1) Development of an improved Zero Air System (and retrofit if possible) to include

a. Optimize the heat cycle of the 1102 air dryer, if possible.

b. Determine whether a small pump and switching valves can be added to the 1102 to provide forced air to drive out water during the heat cycle. *

c. Determine if an activated carbon canisters plus protective DFU filter can be used as a final polishing step and still provide high quality zero air. Coordinate use and information exchange with scientists trying this approach.

Lessons learned:
"I tried this and it seemed to work." (Olson, 2008)

d. Develop a refillable canister with indicating molecular sieve to be used in place of silica gel or drierite as the polishing drying capacity. Molecular sieve has greater water absorption capacity than silica gel or drierite.

Lessons learned:
"Dririte is cheap, we use 2 columns in series so the second one always remains as a polisher."(Felton, 2008)

e. Develop a retrofit for the 1130 pump module that will allow plumbing such that multiple drying and mercury removal canisters can be mounted externally (probably on the 1102 panel) for easy change out.

f. Develop a final disposable prophylactic sorbent trap containing soda lime, activated carbon or other compound which will ensure the zero air is free of halogen or other deleterious compounds, while maintaining mercury free air. The final prophylactic sorbent trap should maintain performance for at least 2 weeks in the very dry and clean zero air stream." (NADP, 2007)

6.12.2.1 Alternative Air Drying Methods

(Expert mercury monitoring feedback in this issue is necessary.)

There was some discussion of Nafion® drying methods at the Atmospheric Mercury Best Practices and SOP Workshop held by NADP in Chicago, IL on Oct 3-4, 2007 (NADP, 2007).

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7.0 Reagents and Standards

(This portion is included for completeness of this SOP, but may not necessarily be important to speciated ambient mercury monitoring. Feedback on this is encouraged.)

7.1 Reagents

"High quality reagents reduce contamination problems" (Poissant, 2008).

7.2 Standards

8.0 Sample Collection, Preservation and Storage

(This portion is included for completeness of this SOP, but may not necessarily be important to speciated ambient mercury monitoring. Feedback on this is encouraged.)

8.1 Sample Collection

*

8.2 Sample Preservation

8.3 Sample Storage

9.0 Quality Control

(Expert mercury monitoring feedback in this issue is necessary)

"Annual audits by certified tech to ensure data comparability between sites." (Olson, 2008)

9.1 Tekran Performance Checks: Quality Assurance Analysis

9.2 Tekran Performance Checks: Quality Assurance Performance Checks

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Specifics regarding quality assurance performance checks were discussed at the Atmospheric Mercury Best Practices and SOP Workshop held by NADP in Chicago, IL on Oct 3-4, 2007 (NADP, 2007). The following is a summary of this discussion:

The Tekran 2537 should be programmed for internal calibration using the internal mercury permeation tube every 72 hours, with a permeation time of 120 seconds.

The operator should maintain a control chart of the internal mercury permeation source calibration factor (CF).

The nominal internal mercury permeation source calibration factor (RespFctr) should be greater than 600,000 (6E5) area units.*

The criterion for an acceptable zero value for internal permeation source calibration should be less than 0.25 pg – this value will be used as a warning flag. ("Good to have this value zero." (Holsen & Choi, 2008; Olson, 2008))

The criterion of an acceptable internal permeation source calibration factor with respect to the A:B gold cartridge difference should be:
warning level: 0.96 – 1.04 ng/m^3 ("Should be shown in SPAN area. Concentrations not compatible with calibration factor" (Holsen & Choi, 2008))
control level: 0.95 – 1.05 ng/m^3 ("Should be shown in SPAN area. Concentrations not compatible with calibration factor" (Holsen & Choi, 2008))
*

10.0 Calibration and Standardization

10.1 Tekran 2537 Detector Calibration

(Expert mercury monitoring feedback in this issue is necessary)
*

10.2 Tekran Performance Checks: Manual Injections or Standard Additions

(Expert mercury monitoring feedback in this issue is necessary)

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"Control charts, spiked denuders (FGS), Injections in impactor and 2537." (Olson, 2008)

Lessons learned:
"I have been running a 2537 for 13 years and it's vital to have the standard addition unit running to assess the quality of the instrument functions… From what I understood this was not possible on the 1130/1135…am I wrong. I think we need something like this for the QAQC – as we do in CAMNet at least to keep up how well the 2537 is performing. As for standard additions for RGM and PHg…we will need some standards. Which I think is something we must work forward on." (Steffen, 2008)

11.0 Procedure and Equipment Settings

This section details how the operator should set up the automated mercury monitoring equipment in a network-standardized manner.

11.1 Mercury Speciation and Data Capture

(Expert mercury monitoring feedback in this issue is necessary as well as NADP input with regards to options for receiving and polling Tekran data)

12.0 Data Analysis and Calculations

This section details procedures and algorithms to manipulate raw data to delineate blanks and calculate other critical values.

12.1 Mercury Speciation Data Reduction and Analysis

(Additional expert mercury monitoring feedback in this issue is recommended)

A speciated data reduction scheme was discussed, developed, and agreed upon by members attending the Atmospheric Mercury Best Practices and SOP Workshop held by NADP in Chicago, IL on Oct 3-4, 2007 (NADP, 2007).

*

There have been a number of comments posted to the previous version of this SOP indicating that atmospheric mercury experts use a number of different techniques to reduce their data – and most feedback on the subject indicated that the previously proposed data reduction scheme is not ideal. Listed below are data and comments to the previously proposed data reduction routine which include

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suggestions from a number of atmospheric Hg experts. A newly proposed data reduction routine is presented here and discussion on this topic is highly encouraged.

Table 12.1 – Tekran GOM and PBM2.5 Data Reduction Routines

Tekran Desorb Program			Tekran GOM and PBM2.5 Data Reduction Routines		
Cycle ID	Description	Flag	USER-ID	PBM2.5 Calculation	GOM Calculation
A	Flush	1			
B	Flush	1		(E+F+G)-3*C	(H+I+J)-3*C
C	Flush	1			
D	Pyro-Ht	2			
E	Part-Ht	2			
F	Part-Ht	2			
G	Part-Ht	2			
H	RGM-Ht	3			
I	RGM-Ht	3			
J	RGM-Ht2	3			
K	Cool	1			
L	Cool	1			

*

13.0 Method Performance

(Expert mercury monitoring feedback in this issue is necessary)

Lessons learned:
"It is important to characterize routine maintenance, calibration, etc as "UP TIME" for billing purposes. These are required activities." (Miller, 2008a)

13.1 Method

"We are in the process of summarizing an inlet study that we made in Alert looking at how much RGM sticks to the inlet. More details will follow." (Steffen, 2008)

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13.2 Precision

13.3 Bias

*

13.4 Representativeness

13.5 Detectability

*

13.6 Completeness

Lessons learned:
"If I calibrate and lose 1 hour in every 72 that's 1.5%, then the servicing every 2 weeks. I think a good goal would be 80%" (Olson, 2008)

13.7 Comparability

Lessons learned:
"Spiked denuders. A collocated unit (WI USGS). Audit Tech." (Olson, 2008)

14.0 Troubleshooting

(further discussion is encouraged)

14.1 Tekran Analyzer Unit model 2537

14.2 Tekran Speciation Unit model 1130

14.3 Tekran Speciation Unit model 1130 – pump module

14.4 Tekran Particulate Unit model 1135

14.5 Other

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15.0 Pollution Prevention

15.1 Pollution

16.0 Waste Management

16.1 Waste

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18.0 Acronym Dictionary

AC – activated charcoal
AMDE – atmospheric mercury deposition event
AMN – atmospheric mercury network
CASTNET – clean air status and trends network
CAMNET – Canadian atmospheric mercury network
CVAFS – cold vapor atomic fluorescence spectroscopy
DFU – dry filter unit
DI – deionized
DIW – deionized water
EPA – environmental protection agency
FTP – file transfer protocol
GEM – gaseous elemental mercury
GOM – gaseous oxidized mercury
GPS – global positioning system
MDE – mercury deposition event
MDN – mercury deposition network
MFC – mass flow controller
MFM – mass flowmeter
MSDS – material safety and data sheets
NADP – national atmospheric deposition program
NIST – national institute of standards and technology
NOAA – national oceanic and atmospheric administration
OSHA – office safety and health administration
PBM2.5 – particulate-bound mercury with a 2.5 μm cut-off
PFA - perfluoroalkoxy
PHg – particulate mercury
PTFE - polytetrafluoroethylene
PVC - polyvinyl chloride
QA – quality assurance
QC – quality control
RGM – reactive gaseous mercury
RPF – regenerable particulate filter
SLT – soda lime trap
SOP – standard operating procedure
TGM – total gaseous mercury
UHP – ultra high purity
USGS – United States geological survey
UV – ultraviolet
VAC – volts (alternating current)
VDC – volts (direct current)

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19.0 Tables, Diagrams, Checklists and QA Worksheets

19.1 Tables

Mercury physical properties

Property	Hg°	$HgCl_2$	Hg0	HgS	CH_3HgCl	$(CH_3)_2Hg$
Melting point (°C)	-39	277	Decomp. at +500°C	584 (sublim.)	167 (sublim)	-
Boiling point (°C)	357 at 1 atm	303 at 1 atm	-	-	-	96 at 1 atm
Vapour Pressure (Pa)	0.180 at 20°C	899×10^{-3} at 20°C	9.20×10^{-12} at 25°C	n.d.	1.76 at 25°C	8.30×10^{3} at 25°C
Water Solubility (g/l)	49.4×10^{-6} at 20°C	66 at 20°C	5.3×10^{-2} at 25°C	$\sim 2 \times 10^{-24}$ at 25°C	~5-6 at 25°C	2.95 at 24°C
Henry's Law Coefficient [Pa m^3 mol^{-1}]	729 at 20°C 0.32 [a] at 25°C 0.18 [a] at 5°C	3.69×10^{-5} at 20°C	3.76×10^{-11} at 25°C	n.d.	1.6×10^{-5} [a] at 15°C And pH=5.2	646 at 25°C 0.31 [a] at 25°C 0.15 [a] at 0°C
Oct.-water part. coef.	4.2 [a]	0.5 [a]	-	n.d.	2.5 [a]	180 [a]

Table A-1 – Mercury physical and chemical properties (Schroeder et al., 1992)

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DRAFT NADP-AMI TEKRAN MODEL 1130/1135 CONTROLLER PROGRAM WORKSHEET

Controller S/W revision:

Description of this Method:

Notes: 1) Flow rate set for near sea-level sites. Sites at higher elevation may adjust to keep volumetric flow at 10 lpm. 2) A 1-hour adsorb time - 1 hour desorb cycle is an acceptable alternative for special source-receptor study sites. The sample durati

Model 2537 Settings

Cycle Time: (sec)	300
Flow Rate: (L/m)	1.00

Pump Module Settings

Sample Flow: (L/m):	9.00
Desorb Flow: (L/m)	6.00

Model 1130 Denuder Module Temperature Settings (deg C)

SP1	Case Heater:	38
SP2	Case Fan:	40
SP1	Heated Line:	50
SP1	Denuder Keep Warm:	50
SP2	Denuder Heat:	500
SP1	Ext. Heat:	75
SP2	Ext Keep Warm:	50

Model 1135 Particulate Module Temperature Settings (deg C)

SP1	Pyrolyzer Keep Warm:	50
SP2	Pyrolyzer Heat:	800
SP1	Part-Trap Keep Warm:	50
SP2	Part-Trap Heat:	800
SP1	Case Heater:	38
SP2	Case Fan:	40

Calculated Values

5.00	Model 2537 Sample Volume (L)
10.00	Denuder Flow Rate (L/m)
1,200	Denuder Total Volume (L)
0.00417	Model 2537 Factor (for ng/m3)
4.167	Model 2537 Factor (for pg/m3)
120	Denuder Sample Time (min)
60	Desorb Analysis Time (min)
180	Total Cycle time (min)
72.0	Auto-Recal interval (hours)

Note: Denuder figures above also apply to the particulate trap.

Au Cartridge Status (GOM & PBM2.5 1st Heat)

Step	Cartridge	Cartridge	Cartridge
1	A	B	A
2	B	-	-
3	**A**	B	A
4	**B**	A	
5	B		
6	A	B	-

Controller Settings

Step No.	Step Label	Step Duration	Duration Units	Event Flags 0 - 7	Sync N=0, Y=1	1130 H/C Mask	1135 L/C Mask	Cumulative Time (sec)	Notes	Time (hrs)
	Auto-Cal	24	GOM-Cycles	n/a	n/a	n/a	n/a			
0	Sample Duration	24	2537 Cycles	0	0	0	0	7200	GOM and PBM2.5 Adsorb tim	2.00
1	Flush	890	sec	1	1	9	0	8100	Three cycle initial flush	2.25
2	Pyro-Ht	290	sec	2	1	9	4	8400	Pyrolyzer preheat	2.33
3	Part-Ht	890	sec	2	1	9	12	9300	Particulate trap heat	2.58
4	GOM-Ht	600	sec	3	0	13	12	9900	Start GOM Heat	2.75
5	GOM-Ht2	290	sec	3	1	13	0	10200	GOM Ht - Stop Py/Pt Ht	2.83
6	Cool	590	sec	1	0	3	2	10790	Two cycle cool	3.00
7	Wait	1	sec	1	1	1	0	10800	Zero air during Sync Period	3.00

Notes:

1) If the Model 2537 is not in **RUN** mode, or if it stops drawing air through its **Sample** Inlet (eg: it stops or the **Zero** solenoid is activated, the controller will immediately jump to the **WAIT** (7) state and wait there until the Model 2537 reenters normal **RUN** mode.
2) A step duration of **0** will cause the step to be skipped entirely.

Event Flags:

1) If the controller changes state midway through a 2537 sample cycle, the resultant event flag will be the logical OR of the flag settings for the individual steps.
2) Event flag status is not sampled for the initial few seconds of each 2537 cycle. If step changes are to occur asynchronously with respect to the sample cycle, the change should occur 1 second ***after*** a cycle change to prevent spurious flag values from being registered. If **Sync=1**, the transition will always occur at the correct time.

Sync:

If Sync is set to Yes (1), the controller will pause at the current step until a Model 2537 cycle transition is detected, even after the duration time expires. The duration should expire at least a few seconds before the expected cartridge switchover.

Model 1130: H/C Mask Functions: — Add numeric values to determine total functions activated during the step

1 Zero Air ON, Desorb Flow RateSelected
2 Denuder Cooling
4 Denuder Heat
8 External Heat

Model 1135: L/C Mask Functions: — Add numeric values to determine total functions activated during the step

1 Aux-1
2 Particulate Cooling
4 Pyrolyzer Heat
8 Particulate Heat

Table A-2 - Tekran model 1130/1135 controller program worksheet

Comments	Instrument	Model	Part #	Total units
Necessary for Tekran 2537A	UV Analytical lamp, 1"	Tekran	90-25180-01	1
	Gold cartridge, matched pair	Tekran	35-25500-00	1
	Zero Air Canister only	Tekran	90-25360-00	1
	0.2μm, 47 μm part. Filters, 100	Tekran	90-25102-100	1
	Inj. Port septum; 100	Tekran	90-25110-100	1
	Rev 2. Cartridge Heater, pair	Tekran	35-25506-12	1
	QG: 1/4" Nut assembly	Tekran	30-25105-00	1
	1/4-28 nut assemblies. (3)	Tekran	30-25300-03	1
	1/4" tubing (per foot)	Tekran	30-35004-047	20
Necessary for Tekran 1130	Impactor disks; pkg of 10	Tekran	30-13127-10	1
	Teflon: 0.2 μm, 47μm Zero Filters; pkg of 100	Tekran	90-13110-100	1
	Heated boot	Tekran	18-13115-00	1
	First Stage Iodated Carbon Zero Filter Canister and DFU Filter	Tekran	90-30360-01	2
	Second Stage Iodated Carbon Zero Filter Canister and DFU Filter	Tekran	90-30360-02	2
	Quartz denuder (body only)	Tekran	30-13100-00	2
Necessary for Tekran 1135	Quartz filter disks for RPF; 0.1 μm, 21 μm dia, pkg of 25. For 1135	Tekran	90-13500-25	1
	Quartz wool RPF fill material; 25 refills. For 1135	Tekran	90-13510-25	1
	GL14-GL18 Union	Tekran	30-13510-00	1
	Teflon 90 Reducing Union 3/8" - 1/4" Elbow	Tekran	30-13520-00	1
	Quartz Regenerable Particulate Filter Assembly (filled)	Tekran	30-13500-00	2
	Have Heater Core on hand! (Olson, 2008)			

Table A-3 – Consumable and parts required to have on hand for uninterrupted and high quality speciated ambient mercury monitoring

Lessons learned:
"Recommend adding spare pumps for 1130, 2537A and spare V2/V3 to the suggested consumable parts. Also add soda lime and/or pre-purged traps." (Miller, 2008a)

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19.2 Diagrams

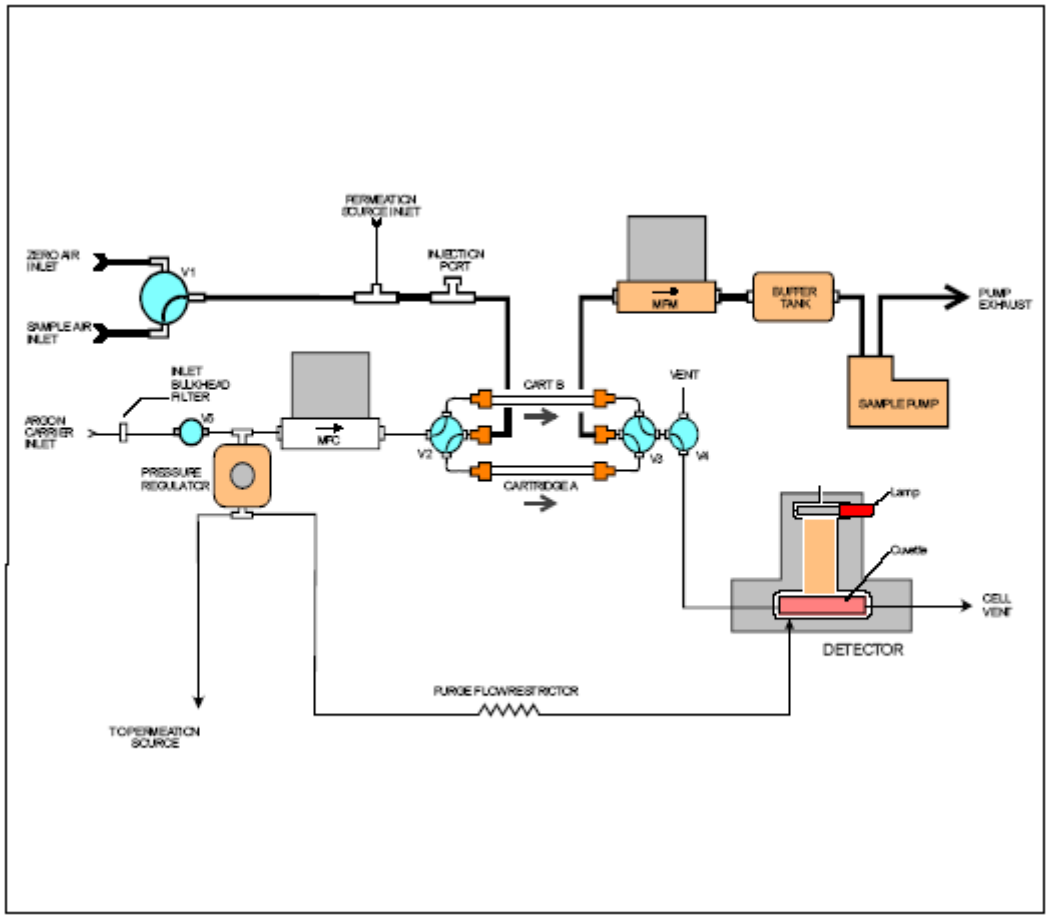

Figure A-1 - (Tekran, 2006c)

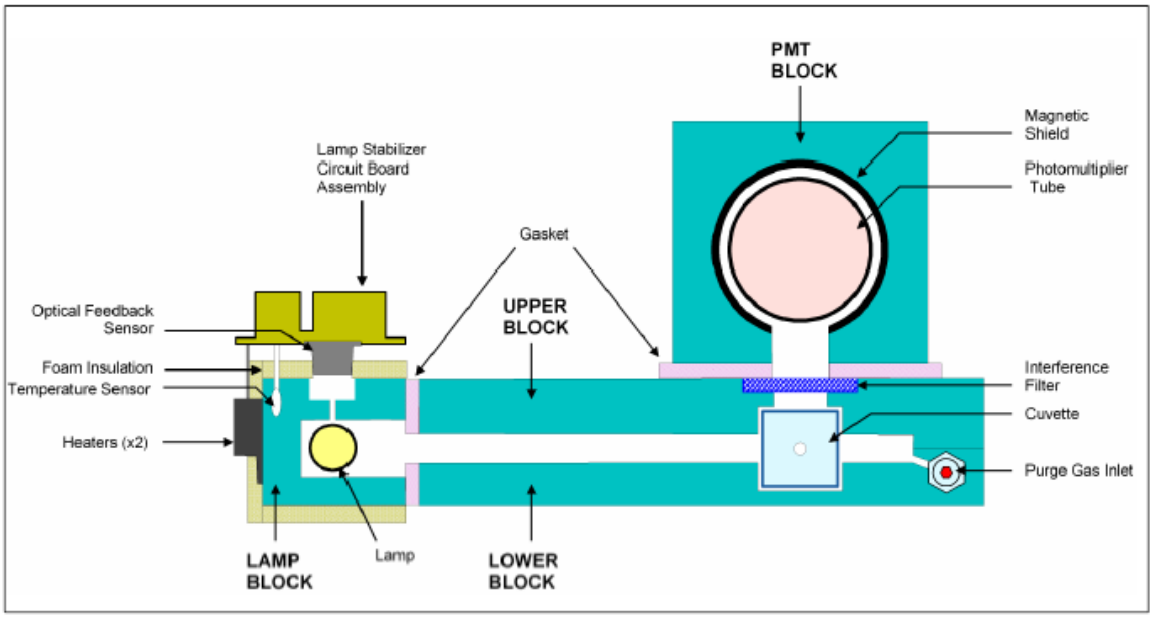

Figure A-2 - (Tekran, 2006c)

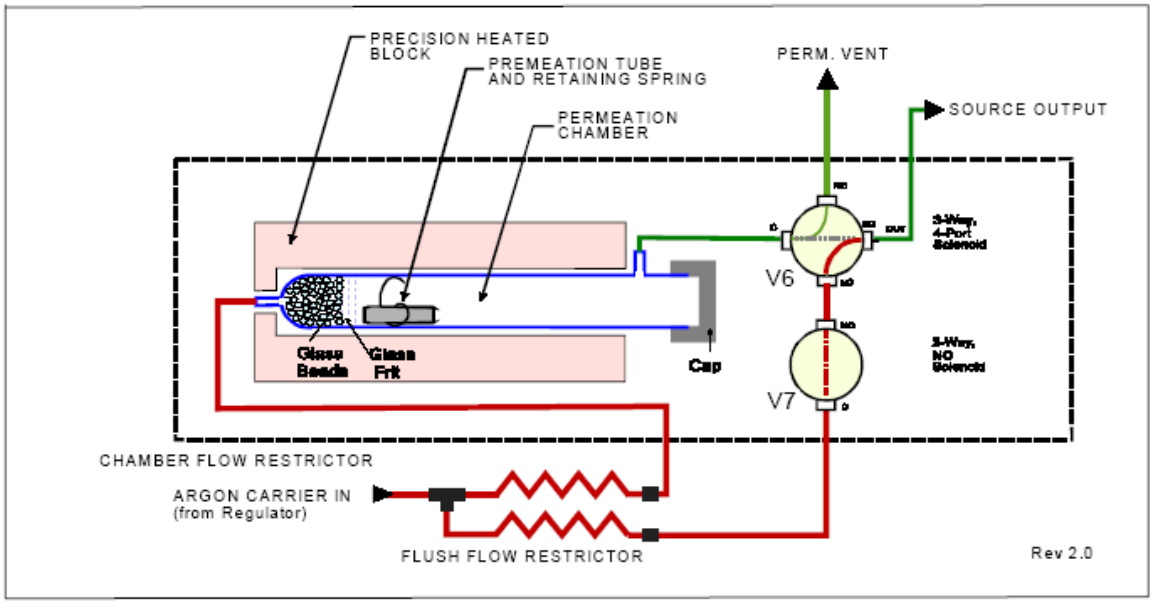

Figure A-3 - (Tekran, 2006c)

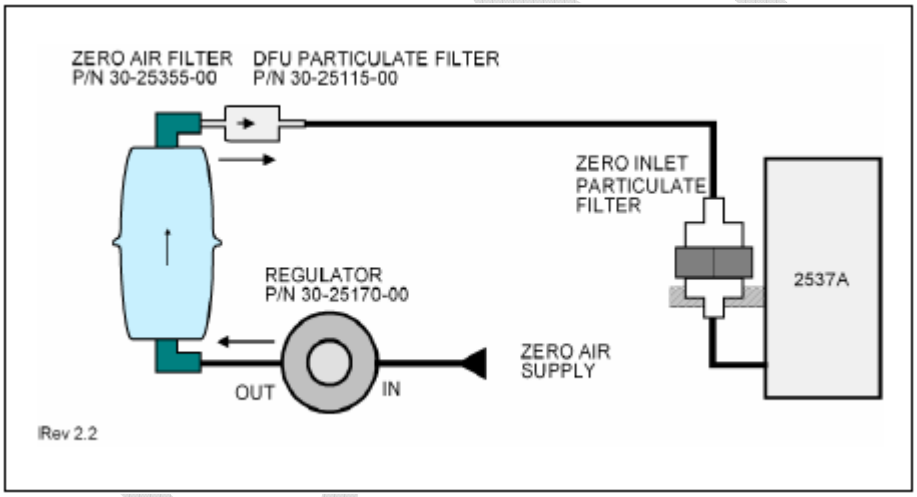

Figure A-4 – Zero air filter and DFU particulate filter for the Tekran model 2537 unit (Tekran, 2006c)

19.3 Field operator maintenance checklists

19.3.1 Daily checklist

Operator Daily Data Checklist and Upload (NOAA, 2006)

Operator: _____
Date: _____
Time: _____
Site: _____

Checks on the Tekran 2537 Monitor
Is the date and time correct? Y/N
(local standard time/NIST/GPS time)
Is the data being recorded correctly? Y/N

Record Tekran 2537 Operation Parameters:
Baseline Voltage (0.9 V - 1.1 V (Holsen & Choi, 2008; Olson, 2008))*
Y/N
Baseline Deviation (<0.100 V (Olson, 2008)) Y/N
Status (should be OK, OKF, or NP(Olson, 2008))
Y/N
Volume (should be =5.0 (Olson, 2008)) Y/N

Lessons learned:
"the SOP flags baseline deviation of > 500 mv….I thought in my past discussions with Tekran, there are serious issues when the baseline voltage gets above 250 mv….."(Dalziel, 2008)
"Agreed – the baseline deviation should be less than 0.1 as listed just above" (Prestbo, 2008)

Zero from Calibration A _____
Zero from Calibration B _____
Span from Calibration A _____RespFctr > 6E5
Span from Calibration B _____

Compare the mean values of the last 4 consecutive elemental mercury results (Flag 0) from CARTRIDGE A and CARTRIDGE B, to ensure that there is no bias (should be within 10% of each other)

"This won't work if concentrations are changing and does not provide enough statistical power. Often traps can have slight difference of 10% that are very short lived. I think the daily check or whatever we agreed upon should be the rule and not a few values" (Prestbo, 2008)

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A _____
B _____
mean difference = _____

Single Heat Cycle Zero Value (Flag 1) _____ (pg/m3)
Does the first particulate heat cycle (Flag 2) show a clear peak response? Y/N
Does the first denuder heat cycle (Flag 3) show a clear peak response? Y/N

Has data been commented (valid, invalid, Questionable), graphed and uploaded? Y/N

Lessons learned:
"The daily check list – I would have the site operator also check the 1110 Tekran dryer …I have had two or three occasions when my unit was not working …after a power failure ….it is a very quick and easy thing to check…i.e. Is the unit warm at the top?...." (Dalziel, 2008).

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19.3.2 Weekly checklist

Operator Weekly Site Visit (NOAA, 2006)
(roughly 2 hours – observing one complete cycle)

Operator: _____
Date: _____
Time: _____
Site: _____

Argon cylinder pressure _____ psi
Regulator should be set to 50 psi.
Replace argon gas when the pressure in the cylinder is below 300 psi.
Don't switch off unit during a calibration or desorb. Turn instrument OFF when changing the cylinder. (See Argon Cylinder Safety section)

Lessons learned:
"If you're fast, no need to shut down instrument. Do it during non flush or heating…" (Olson, 2008).
"Regarding the regulator setting, "I run all my Tekran instruments @ 30." (Olson, 2008)

Lamp indicator light On/Off
If "on" request lamp change

Perm indicator light Flashing/Steady/Off
(should be flashing)

Checks on Pump Unit (*yes*/*no*):
Are the four 1130 pump module cycle switches on auto? Y/N
Are the three 1135 pump module cycle switches on auto? Y/N
Is the 1130 pump module flow switch set to auto? Y/N
Does the indicated pump flow rate match the flow set point? Y/N
Record Tekran 1130/1135 Operation Parameters (Holsen & Choi, 2008; Olson, 2008):
Sampling and analysis (S&A) vs. Desorbtion (Desorb) temperatures:
Denuder temperature: S&A (°C)_ _50 Desorb(°C)_____500
Pyrolysis temperature: S&A (°C)_ _50 Desorb(°C)_____800
Particulate temperature: S&A (°C)_ _50 Desorb(°C)_____800
Sample Line Temperature: S&A (°C)____50
External Heater Temperature: S&A (°C)_ 50 Desorb(°C)_____75
Case Temperature 1130: S&A (°C)____38
Case Temperature 1135: S&A (°C)____38

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Are the heating cycles up to the correct temperatures? Y/N

Pyrolysis - 800°C; Particulate - 800°C; denuder - 500°C

Inlet visually checked for insects or clogs? OK/Insects/Clogged

Top of 1102 Air dryer unit warm? Warm/Cold

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19.3.3 Bi-weekly checklist (Swartzendruber et al., 2006)

Bi-Weekly QA List: Maintenance and Tasks and QC Measurements

Date	Data recorded properly	Change denuder	Rinse inlet	Boot temp.	Lamp volt.	Change 1130 filters	Change inlet glassware	Inspect boot	Inspect tubing
MM/DD/YYYY	y/n	y/n	y/n	~50 C	8-9 V	y/n	y/n	pass/ fail	pass/ fail
12/07/2007	y	y	y	48	8.5	y	y	Pass	Pass

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19.3.4 Monthly checklist

Monthly QA List: Maintenance and Tasks and QC Measurements

Date	Change RPF	Confirm Vol. Flow rate	Comments
MM/DD/YYYY	y/n	9-11 L/min	[range]
12/07/2007	y	9.5	[example]

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19.3.5 Quarterly checklist

Quarterly QA List: Maintenance and Tasks and QC Measurements

Date	Audit MFM in 2537	Audit MFM zero air in 1130 pump	Verify 2537 by man. Injection	Check nichrome heater coil	Install new 2537 Teflon sample filter + clean housing	Install new 2537 zero air filter + clean housing	Comment
MM/DD/YYYY	y/n	y/n	y/n	y/n	y/n	y/n	[range]
12/07/2007	y	y	y	y	y	y	[example]

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19.3.6 6-Month checklist

6-Month QA List: Maintenance and Tasks and QC Measurements		
Date	Change both of the 1130 pump unit zero air carbon canisters + DFU filters	Comments
MM/DD/YYYY	y/n	[range]
12/07/2007	y	[example]

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19.3.7 Annual checklist

Annual QA List: Maintenance and Tasks and QC Measurements

Date	Replace heater coils	Install 2537 zero air canister	New Teflon RPF elbow + tubing	Teflon tubing other	Rinse/ install new tubing in 1130 pump	Replace GL14-18 union	Independent QA audit	Comments
MM/DD/YYYY	y/n	y/n	y/n	y/n	Rin/inst	y/n	y/n	[range]
12/7/2007	y	y	y	y	y	y	y	[example]

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19.3.8 As-Needed checklist

As-Needed QA List: Maintenance and Tasks and QC Measurements

Replace gold cart. In 2537	Clean Teflon valves	Install new Teflon valves	Clean quartz fluor cell	Replace quartz fluor cell	Replace 2537 lamp	Comments
MM/DD/YYYY	MM/DD/YYYY	MM/DD/YYYY	MM/DD/YYYY	MM/DD/YYYY	MM/DD/YYYY	[range]
12/7/2007	12/7/2007	12/7/2007	12/7/2007	12/7/2007	12/7/2007	[example]

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19.4 Field operator quality assurance worksheets

(Expert mercury monitoring feedback in this issue is necessary)

19.5 Field audit quality assurance worksheets

(Expert mercury monitoring feedback in this issue is necessary)

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